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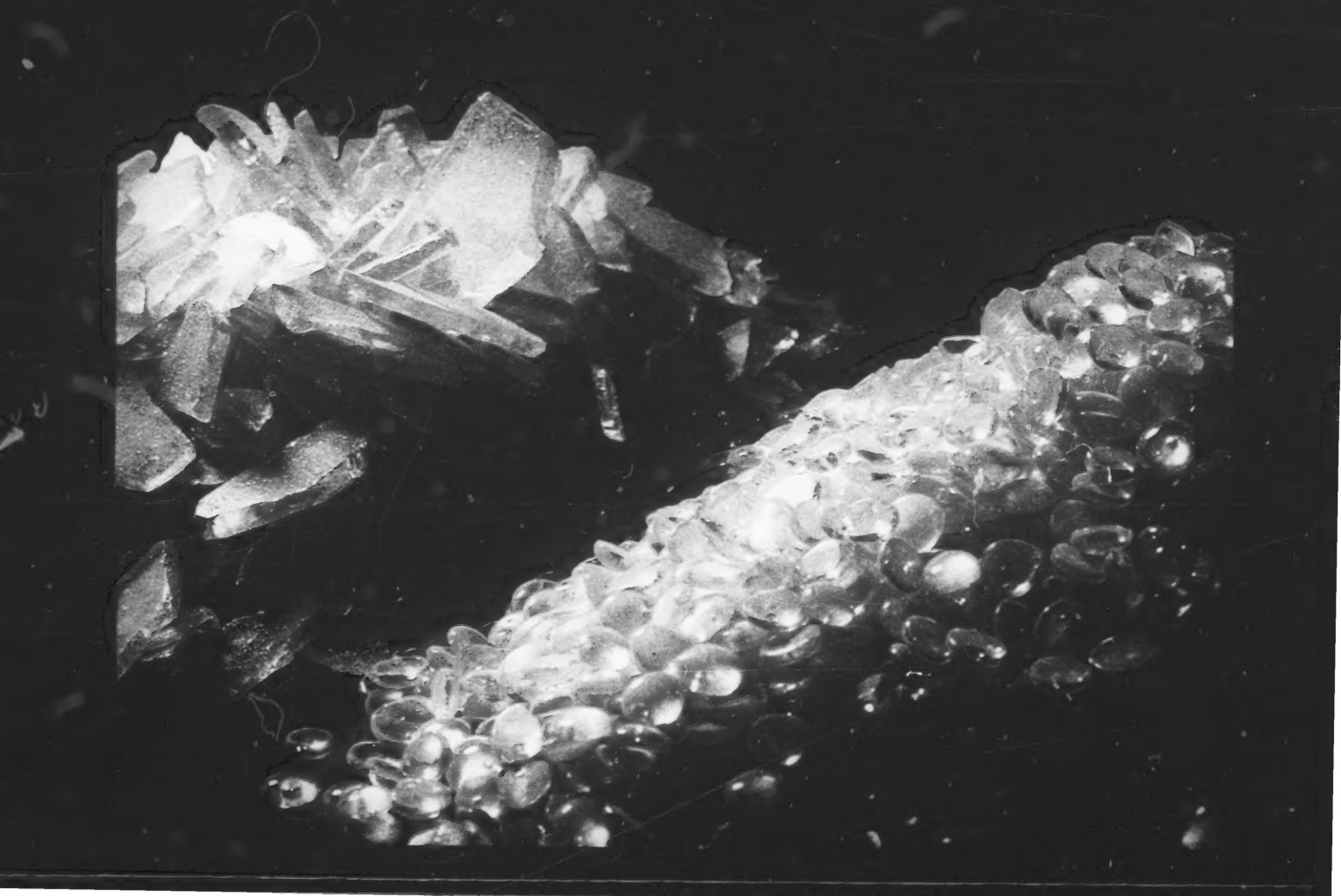
RubberWorld

Formulating TPEs for adhesives

FKM in expansion joints

Tire cord to NR adhesion

Optimizing CB loading for explosive decompression resistance



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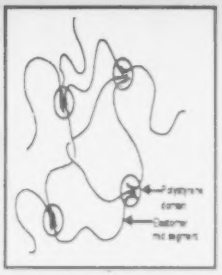

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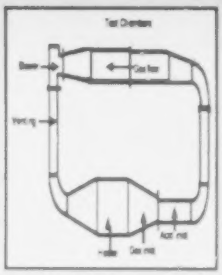

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Acquisitions, expansions; contracts, licenses; financial statements; markets, news.

12 Tech Service: Thickness - a sound alternative
by Jon Menough, contributing technical service editor. This month's column looks at a non-contact thickness measuring gauge developed for use in the rubber industry by Ultrasonic Arrays.

14 Urethane Forum: New polyurea/amides for easier processing
Column examines a new class of polyurea/amide RIM elastomers from BASF, which can be processed easily on standard high pressure mixing machines in the advanced development stage. Flexible foam technology from Dow Chemical, and reaction foaming machines from Klockner Ferromatik Desma are also featured in this month's column.

16 Formulating TPEs for adhesives
by Kendall F. Foley, Hercules, Inc. The author reviews the concepts involved in formulating thermoplastic block copolymers for adhesives.

24 FKM in flue duct expansion joints
by R.J. Arhart and W. Roman, Du Pont. This article describes a laboratory test chamber used to evaluate compound selection by exposure to corrosive flue gas.

36 Optimizing carbon black loading for explosive decompression resistance of fluoroelastomers for oil field service
by L.A. Peters and J.C. Vicic, FMC Central Engineering Laboratories, and T.L. Pugh, Conoco-PRD. This article extends the previous work done on tire tread compounds to the study of fluoroelastomer compounds, which are the performance elastomers of the oil patch.

40 A novel system for nylon-6 tire cord to natural rubber adhesion
by Rakesh Jain and Golok Bihari Nando, Indian Institute of Technology. This study deals with the adhesion of both dipped and undipped nylon-6 cord to natural rubber bonding in the presence of the dry bonding agents.

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Cover photo courtesy of Hercules, Inc.

A Lippincott & Peto Publication

Editorial

Kudos to the Rubber Division for an excellent meeting in Cincinnati. As usual, the technical program was top notch. The attendance figures tell you that. The "Mini" Expo was a hit. The number of those signing up for the next one in Washington, D.C. attests to that. This experiment appears to be a huge success and we applaud the decision to continue this off-expo year exhibit of suppliers to this industry. This show exceeded most attendees' expectations in quality and quantity, and will be a welcome addition to these meetings.

The Division announced the formation of two new rubber groups, or subdivisions. They are the St. Louis Rubber Group and the Thermoplastic Elastomers Topical Group. The former is formed along the traditional rubber group way - by geographical area - and the latter is a departure from the norm, but appears to be the first of other groups formed devoted to a single subject. The TETG is a result of a Division ad hoc committee recommending the division to form such associations. This looks like a good move by the Division. It's no secret that the Rubber Division isn't the only association vying for its members. It's also no secret that those in the elastomer industry consider TPEs as theirs, as do members of the plastics industry. Regardless of where these materials fall, creating a rubber group specifically for them can only benefit the Division, its members and the participating companies.

The creation of the TETG also shows a flexibility within the Division to adapt to new technologies as they arise. It should make for stronger technical meetings because of the more defined focus the group will bring to its symposia. It also paves the way for similar, single interest groups, to be formed and take part in the biannual meetings. Tires is one that comes to mind.

One decision the Division made at the Cincinnati meeting that doesn't sit too well is the announcement there would be no Sparks-Thomas award winner for the second year in a row. This award, which is to recognize and encourage outstanding scientific contributions and innovations in the field of elastomers by younger scientists, technologists or engineers, has only been awarded once since its inception three years ago. We feel not awarding this reflects badly on the Division and does anything but encourage younger members. One award announcement, that Ben Kastein would receive the Distinguished Service Award, we applaud heartily. Anyone who has been involved in the Rubber Division is aware of Ben's contributions. The former division chairman and now historian, has given nothing but distinguished service to the Division and the rubber industry. Ben was also a technical editor for *Rubber World* and his contributions were exemplary. A real deserving choice for this award.

Don R. Smith
Editor

RubberWorld

EDITORIAL STAFF

Don R. Smith editor
Dr. Walter C. Warner technical editor
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Deanne Dodd composition editor
Jon Menough contributing technical service editor

BUSINESS STAFF

Job Lippincott publisher
John W. Peto v.p. sales
Barbara Gordon adv. production manager
Jane McBee assistant adv. production manager

EDITORIAL OFFICES

P.O. Box 5485
1867 W. Market Street
Akron, Ohio 44313
(216) 864-2122
Telex: 297690 RWMAG UR

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- Product News
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Business Briefs

technical service resources around the world.

Uniroyal also acquired the rights to manufacture and market the complete product line of ambient-cured sprayable, castable and trowelable urethane systems developed by **Wear Resistant Materials Pty.**, of Australia.

Monsanto Chemical is doubling the production capacity for Santoprene rubber at its plant in Newport, South Wales. The expansion is to be completed by mid 1989.

Monsanto has also completed the product form improvement and packaging automation phase of a $14 million modernization project at its Nitro, WV plant. The total project is to be completed in 1990.

General Electric will invest $1.7 billion dollars over the next 15 years in a new plant in Cartegena, Spain. It will be the first basic silicones investment in Europe and will become part of the proposed **GE/Union Carbide** joint venture, **GE Carbide Silicones.** The facility will initially produce silicone and will later add polymers from the company's plastics product line.

Dow Chemical is expanding global production capacity for polyether polyols by building new plants in Taiwan and Columbia, each with over 30 million pounds of capacity; an incremental expansion of the Brazilian facility of more than 20 million pounds for specialty polyols; and a 55 million pound increase at the Freeport, TX facility.

Polysar has opened a new technical center in Akron, OH to support the polymers sealants/adhesives business worldwide.

RMA tire report through June
(figures in thousands of units)

Passenger tires	YTD '88	YTD '87	% change
Shipments			
original equipment	35,383	35,602	-0.7
radial	30,131	30,191	-0.2
replacement	101,797	97,263	4.7
radial	95,120	86,860	9.5
export	6,300	3,703	70.1
radial	5,572	3,226	72.7
total	143,459	136,568	5.0
radial	130,823	120,277	8.8
Production	116,442	110,607	5.3
radial	105,838	96,905	9.2
Truck & bus tires			
Shipments			
original equipment	5,879	5,265	11.6
radial	4,293	3,656	17.4
replacement	22,187	22,335	-0.7
radial	12,915	11,945	8.1
export	2,157	1,285	67.8
radial	1,672	909	84.0
total	30,222	28,886	4.6
radial	18,880	16,510	14.4
Production	24,300	23,326	4.2
radial	14,877	13,202	12.7

BASF opened a thermoplastic polyurethane applications development lab in Wyandotte, MI.

Air Products and Chemicals established a coatings lab near Allentown, PA. The company also announced its **Anchor Chemical** unit has taken over the Impex epoxy curing agent business of the **Penultimate Corp.** of Huntington Beach, CA.

Amoco Performance Products has begun construction on a multi-million dollar compounding facility in Geel, Belgium. The company's first overseas plant will compound a range of engineering polymer products for the European market and is scheduled to be completed by the end of next year.

Castrol Inc. will purchase **Chem-Trend,** Howell, MI for $46 million. Chem-Trend, a supplier of mold release agents has manufacturing facilities in Denmark, the UK, France, Sweden, South Korea, Mexico and Brazil.

Jasper Rubber Products is undertaking a $1.5 million expansion to add 25,000 sq. ft. to its Jasper, IN plant. Some of the new footage will be used for new rubber and silicone injection presses.

Midwest Elastomers has begun operations of a new specialty grinding department to process high-value polymers.

Nassau Chemical has been merged into its parent company, **Wyrough & Loser, Inc.**

Bridgestone acquired **Good-Wear Treaders Ltd.**, an independent tire dealer in Atlantic Canada.

DSM Resins opened new research laboratories at Zwolle, The Netherlands.

Ashland Chemical acquired **Royell, Inc.**, Menlo Park, CA, a distributor of glass reinforcements, unsaturated polyester resins and other fiber-reinforced plastic materials.

ICI Fluoropolymers is undertaking a $40 million project at its Bayonne, NJ facilities that includes constructing a new fluoroethylpropylene plant and doubling of fluoromonomer production.

Jack Scheidell, formerly with R.E. Carroll and Sun Refining, has established **Jack Scheidell & Son** in Trenton, NJ to serve as sales consultants and manufacturers representatives.

Bohlin Reologi has opened a regional sales office in Chicago, IL for its rheological testing instrumentation.

D&A International, Sacramento, CA is building a $2.5 million latex centrifuging plant in Sri Lanka. The company is also forming a joint venture with the Sri Lankans to build a $5.5 million latex glove manufacturing plant that will produce 250 million latex examination gloves annually upon completion in September, 1989.

Firestone Building Products purchased the assets of **Teltex/ICM,** North Branford, CT, a manufacturer of modified bitumen roofing products.

Mercer Products, an operating unit of **Dexter Plas-**

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The technical magazine Volume December 1988

Dynamic rubber in automotive parts

Advances in acrylic cure technology

Engineered TPEs for automotive applications

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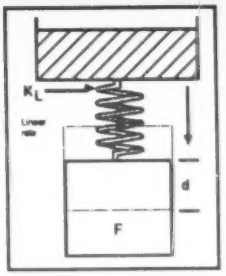

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10 Tech Service: Fibers: What's down the road
by Jon Menough, contributing technical service editor. This month's column looks at a number of new fiber products that could find applications in the rubber industry.

12 Urethane Forum: New aspects in the development and application of thermoplastic polyurethane
by H.-G. Hoppe, Bayer AG. A look at the new areas in which TPUs are being developed to meet changing requirements.

14 Dynamic rubber in automotive parts
by Donald S. Novotny, Cooper Industrial Products. The author reviews tests and equipment used for measuring rubber properties, looks at isolators and dampeners, and explores the use of rubber and rubber compositions in automotive parts.

20 Advances in acrylic elastomer cure technology
by Robert M. Montague, BFGoodrich Elastomers and Latex Division. This article looks at technology developed to provide fast curing, low compression set behavior in acrylic elastomers.

26 Engineered thermoplastic elastomers for non-tire automotive applications
by Edwin P. Tam, Mark A. Wright, Robert L. Arnold and Michael W. Bednarik, Monsanto Chemical. This article provides an overview of TPEs, along with reasons why automotive parts designers and material engineers are selecting TPEs for applications such as interior and under-the-hood parts.

31 Dynamic behavior of compounds containing highly reinforcing carbon blacks with equilibrium cure system
by E.H. Tan and S. Wolff, Degussa AG. This article looks at how dynamic properties depend on the degree of loading, crosslinking density and crosslinking structure, and investigates the differences in dynamic properties observed on vulcanizates with normal cure, semi-EV and equilibrium cure systems.

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edited by Bob Samples, Akron Rubber Development

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Cover

Cover photo courtesy of GenCorp.

A Lippincott & Peto Publication

Editorial

It's ironic that the announcement by the government that it might not approve a proposed merger of the silicone businesses of Union Carbide and General Electric came on the heels of the announcement that Degussa was buying the carbon black business of Ashland Chemical. Ashland ran afoul of government anti-trust rules a few years ago when it thought it would make itself more competitive in the carbon black market through the purchase of Phillips Chemical's carbon black business. The government trust busters stepped in and nixed the deal. They claimed it would reduce competition in this market. Phillips, wishing to divest these operations, sold its European and African operations to Degussa and one of its U.S. plants to Sid Richardson Carbon. Degussa of West Germany then completed acquisition of what would have been the Ashland/Phillips business with its recent announcement. There has been no indication from the government of a challenge to this formation of the second largest carbon black producer in the world.

But the government is objecting to the formation of the second largest silicone producer in the world. The Federal Trade Commission has stated the formation of GE-Carbide Silicones could substantially lessen competition in both production and sale of silicone products. GE is the second largest silicone producer worldwide and Union Carbide ranks sixth. GE is second and Carbide third in U.S. production.

The problem this proposed union is having is that both are U.S. based and the rules governing such activity are antiquated and apparently out of tune with what the rest of the federal bureaucracy is attempting to do with trade. The problems with U.S. anti-trust laws have been addressed many times. The Reagan administration's Justice Dept. has revised merger guidelines twice. Both times the intent was to increase the competitiveness of American business. They were bureaucratic responses to the rising imbalance of trade. Political rhetoric toward the woes of U.S. industries' claim of competing on an uneven playing field usually resulted in the industry being blamed. Industry was told there was no longer just an American market, that now it was a world marketplace. American business was told they were going to have to rethink their market positions into global terms.

Some have, and maybe the conclusions called for mergers, acquisitions, joint ventures or licensing agreements. And maybe the scope of their decisions wasn't large enough to wake the lawyers at the Justice Department or the FTC. This isn't the case for GE or Carbide, they're going to have to get more competitive some other way. Like letting some foreign firm acquire both of them.

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Business Briefs

Acquisitions, expansions

Cooper Tire & Rubber is constructing a 40,000 sq. ft. addition to its automotive hose, tubing and body seal plant in Bowling Green, OH. A 20% increase in production capacity is to be realized upon completion in 1989. The new building addition will be used for warehousing and storage. The current warehouse area will be converted to increased production of extruded, molded and formed automotive hoses and tubing, and dual durometer body sealing products.

Monsanto will undertake a multi-million dollar project that will increase thermoplastic elastomer production by 150% at its Pensacola, FL plant. The expansion is expected to be completed early in 1990.

Polysar announced capacity expansions for ethylene and polystyrene resins. A $50 million (Canadian) expansion at the Corunna, Ontario manufacturing facility will increase ethylene capacity 20%. Upon completion during the first quarter of 1990, the plant will have an annual capacity of 1.2 billion pounds. The company plans on adding 300 million pounds of polystyrene resin capacity over the next two years. A major expansion is underway at the Decatur, AL plant that will add 200 million pounds.

A major plant investment program has been completed at **Cadillac Rubber's** Cadillac, MI plant. Six new transfer molding machines will increase transfer press capacity by up to 25% and two injection presses have been added.

Degussa is building a 5 million pound per year organosilanes plant at its Mobile, AL chemical complex. The preliminary product will be a bifunctional polysulfidic organosilane used to improve reinforcing and crosslinking properties of rubber to rubber and rubber to filler compounds.

BFGoodrich is undergoing a $22.9 million expansion and renovation of its R&D center in Brecksville, OH. A new 75,100 sq. ft. building and a 23,700 sq. ft. expansion of the main building are planned and are expected to be completed in 1990.

Ferro Corp. purchased the **Leglo Color Co.**, Huron, OH, a division of **Harwick Chemical**. Leglo manufactures specialty color and additive concentrates and dry color blends.

D&A International, Sacremento, CA is building a $2.5 million latex centrifuging plant in Sri Lanka. The company is also creating a joint venture in Sri Lanka to build a $5.5 million latex glove manufacturing plant that will produce 250 million latex examination gloves annually.

Exxon Chemical is proposing to build a $40 million normal-paraffins plant at Sri Racha, Thailand. Annual capacity will be 80,000 tons, over half of it for export. The plant would be operational 30 months after government approval. Exxon also announced it will build a high density polyethylene resin plant in Mont Belvieu, TX with an annual capacity of 265 million pounds.

DSM Chemical has opened a sales office in Atlanta, GA for its products which include caprolactam, ammonium sulphate, surfactants and chemical specialties.

Columbian Chemicals formed a division for the production and marketing of its iron oxide line. The Mapico Division will be located in St. Louis, MO.

Ashland Chemical acquired **Royell, Inc.**, a Menlo Park, CA based distributor of glass reinforcements, unsaturated polyester resins and other materials to manufacturers of fiber-reinforced plastic products.

RMA rubber report through June
(figures in metric tons)

	YTD 1988	YTD 1987	% chg.
Total new rubber			
New rubber available	2,302,698	2,179,882	5.6
Imports	751,218	742,572	1.2
Exports	385,667	330,034	16.9
Apparent consumption	1,888,986	1,844,955	2.4
Total natural rubber			
Imports	573,255	551,684	3.9
Exports	32,747	23,283	40.7
Apparent consumption	543,075	526,578	3.1
Total synthetic rubber			
Production	1,551,480	1,439,310	7.9
Imports	177,963	190,888	-6.8
Exports	352,920	306,751	15.1
Apparent consumption	1,345,906	1,318,372	2.17.8
Total SBR			
Production	601,589	559,146	12.0
Imports	60,971	54,455	16.1
Exports	129,987	111,925	1.8
Apparent consumption	512,951	503,894	
Total nitrile			
Production	49,452	43,825	12.8
Imports	10,885	10,278	5.9
Exports	10,903	9,044	20.6
Apparent consumption	50,165	43,934	14.2
Polybutadiene			
Production	270,334	240,882	12.2
Imports	55,287	57,743	-4.3
Exports	41,627	41,967	-.8
Apparent consumption	273,890	258,653	5.9
Ethylene-propylene			
Production	177,767	167,719	6.0
Imports	8,016	4,014	99.7
Exports	37,435	31,152	20.2
Apparent consumption	148,511	135,193	9.9
Butyl, polychloroprene, polyisoprene, silicone and other synthetic elastomers			
Production	451,337	425,738	6.0
Imports	42,804	64,398	-33.5
Exports	132,968	112,663	18.0
Apparent consumption	360,389	376,700	-4.3

Business Briefs

Fisons Instruments will begin operations in January, 1989. The Valencia, CA firm will consolidate existing sales, service and technical support in North and South America for the product lines from **Applied Research Laboratories, Haake Instruments** and **Carlo Erba Instruments.**

HBI/Haake Buchler Instruments, Saddle Brook, NJ sold its Buchler product line to **Labconco Corp.,** Kansas City, MO. The Buchler line consists of products for electrophoresis, liquid chromatography and evaporation.

Progressive Machine Co. built a new manufacturing and headquarters building in Ringwood, NJ for its spooling and traverse winding systems.

U.S. elastomer production and sales, 1987

Elastomers	Production	Sales Quantity	Value	Average unit value
	1,000 pounds	1,000 pounds	1,000 dollars	Per pound
Grand Total	4,690,358	3,108,761	2,714,048	$.87
Butadiene-acrylonitrile type (NBR-type)	142,238	96,544	93,666	.97
Ethylene-propylene type (EP-type)	521,673	441,837	317,852	.72
Polybutadiene (solution polymerized) type (BR-type)	689,665	338,399	151,633	.45
Silicone (Q) type elastomers	186,010	142,267	494,283	3.47
Styrene-butadiene type (SBR-type)	1,828,911	993,158	458,654	.46
Styrene-butadiene-vinylpyridine type	20,936	10,098	11,000	1.09
Thermoplastic elastomers (such as styrene block copolymers, thermoplastic olefin elastomers, thermoplastic polyurethane elastomers, and co-polyesters)	421,997	364,277	401,841	1.10
All other elastomers	878,928	722,181	785,119	1.09

Contracts, licenses

Goodyear and **EMS Chemie** of Switzerland signed an agreement where **EMS-American Grilon** will sell Goodyear produced hydroxyl functional resins along with its carboxyl resins in North America. Goodyear's Point Pleasant, WV plant will modify production lines to be able to produce both types.

Sears has added **Bridgestone** tires to its product line in its 803 Tire and Auto Centers.

DSM has granted Czechoslovakia's **VUGPT** (Rubber and Plastics Technology Research Institute) the license to develop DSM's Nyrim nylon block copolymers in CSSR.

Tech Sales Co., Downsview, Ontario, Canada has been appointed manufacturers representative by **Hydralign, Inc.** for its web guiding systems and other web-processing related products.

Financial statements

American Biltrite reported third quarter net earnings were $403,000 on sales of $38.5 million.

BP Chemicals reported that profit for the third quarter was $207 million.

NL Industries' chemicals business reported operating income of $73.1 million on sales of $246.9 million for the third quarter.

Park-Ohio reported a third quarter loss of $58,000 on sales of $30.4 million.

Markets, news

The U. S. Industrial Trade Commission's report on synthetic organic chemicals shows that production of synthetic rubber in 1987 increased 14.9% from 1986 to 4.69 billion pounds. Production has increased 16.9% since 1983. Total sales of elastomers in 1987 amounted to 3.1 billion pounds, a 25% increase over 1986. SBR use accounted for 1.85 billion pounds which includes 21 million pounds of vinylpyridine. Polybutadiene production reached 690 million pounds, while production for other elastomers showed EPDM production at 522 million pounds, butadiene/acrylonitrile at 142 million pounds, silicones at 186 million pounds and thermoplastic elastomer production was 422 million pounds.

The United States Federal Trade Commission is seeking a preliminary injunction to block the silicone joint venture proposal of General Electric and Union Carbide. The FTC

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RubberWorld

The technical service magazine for the rubber industry

Volume 199, No. 4

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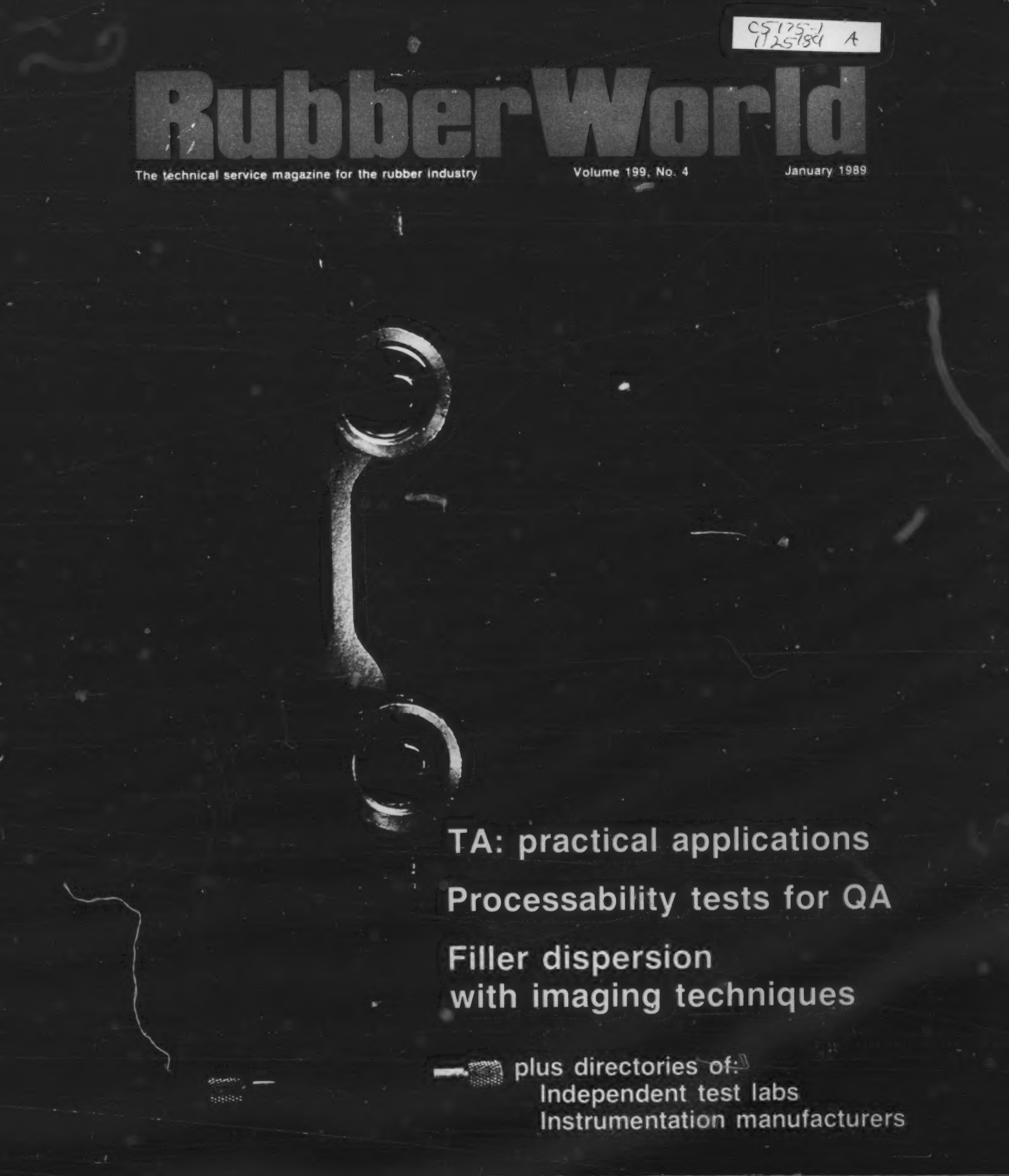

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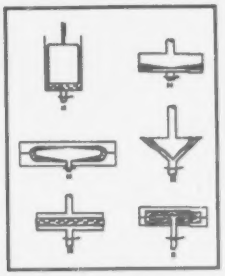

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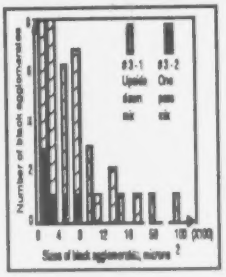

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Acquisitions, expansions; contracts, licenses; financial statements; markets, news.

8 Tech Service: Fluoroelastomer coatings - a review
by Jon Menough, contributing technical service editor. This month's column looks at how demands for higher temperatures and resistance to more corrosive environments has expanded the need for high performance fluoroelastomer coatings.

12 Urethane Forum
News items reviewed in this column concern EPA assistance in CFC phase-out; an award for a non-pneumatic spare tire received by Uniroyal Goodrich; and a cast polyurethane textbook.

14 TA: Practical applications for chemical reconstruction of rubber compounds
by Richard L. Zeyen III, Cooper Tire and Rubber. The author reviews the theory, history and practical applications of both thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC).

21 The use of processability tests for quality assurance
by John A. Sezna, Monsanto Co. This article discusses the types of processability tests available for the rubber industry, and methods for applying those tests to the goal of quality assurance.

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Cover photo courtesy of E-A-R Division, Cabot Corporation.

A Lippincott & Peto Publication

Editorial

The evolution of quality in American business has been startling over the last two decades. What used to be deemed acceptable quality just 20 years ago will put you out of business in today's manufacturing climate. The incorporation of statistical process control techniques has led to the development of sophisticated instrumentation aimed at insuring process control prior to manufacturing. The position of quality inspector has all but vanished as has the practice of selling blemished products.

What all this has done is tighten up tolerances and minimized errors and defects. It has also reduced the percentage that is thought of as being an accepted quality level. Just two decades ago 5% was looked on as an acceptable level for errors or defects. Today, that figure is more like 1% or less and is still shrinking. In fact, QCI International, a quality improvement training firm says that 99.9% right isn't good enough.

Jeff Dewar, a researcher for QCI says, "As we enter the 1990s, 100% perfection, not accepted quality levels, will become the predominant philosophy." Here is what QCI says it would be like in the U.S. if things were done right 99.9% of the time. It would mean:

- one hour of unsafe drinking water per month
- two unsafe landings at O'Hare International Airport each day
- 16,000 lost pieces of mail per hour
- 20,000 incorrect drug prescriptions per year
- 500 incorrect surgical operations performed each week
- 50 newborn babies dropped at birth by doctors each day
- 22,000 checks deducted from the wrong accounts each hour
- 32,000 missed heartbeats per person each year.

The unsettling thing about these figures is that they represent a margin of error of only .001%. A figure that is deemed acceptable in many manufacturing operations.

It is inevitable that many buyers of rubber products, especially those in the automotive field, will be demanding 100% quality. In turn, the product manufacturers will be demanding the same from their suppliers. The machinery and instrumentation have evolved right along, pushing the quality number as close to 100% as possible. The real change that has to be made is in corporate philosophy. The tools are there.

Don R. Smith
Editor

RubberWorld

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Jon Menough contributing technical service editor

BUSINESS STAFF

Job Lippincott publisher
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Barbara Gordon adv. production manager
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EDITORIAL OFFICES

P.O. Box 5485
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- Blue Book: Materials, Compounding Ingredients, and Machinery for Rubber

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Sales of analytical laboratory instruments to more than double by 1997

Technology advances in the U.S. analytical instruments industry such as the integration of semi-conductors, fiber optics, artificial intelligence and other information processing techniques are fueling market growth and broadening the applications for these devices, according to a report by New York-based research firm FIND/SVP.

Intelligent instruments are increasingly being used as an integral part of Laboratory Information Management Systems - networks which orchestrate the gathering, retaining, organizing and distributing of laboratory information. Additional technological developments in physics and engineering have the potential to improve both the technical performance and price structure of analytical instruments.

These devices used to investigate physical and chemical properties like mass, volume, density, electrical charge, resistivity, conductance and radioactivity, achieved sales of almost $3 billion in 1987, up an average of 8.3% a year from sales in 1982 of just under $2 billion. By 1997, sales are projected to reach $7.7 billion.

Presently, the market contains only a handful of manufacturers of any appreciable size, with no single competitor dominant in all segments and no evidence of an impending shakeout. The top 50% share of the market is divided among 11 competitors, with the top 60% controlled by 25 players.

Although no foreign competitor has yet made inroads in capturing significant market share, foreign suppliers have had some success entering the market through OEM agreements in the lower technology segments. However, the general trend toward more software-intensive instruments may further create barriers for offshore competition. The report notes that analytical instruments have generated trade surpluses (exports exceeding imports) since World War II and should continue to do so. Last year, the trade surplus stood at $677 million, having grown nearly 11% a year from 1982. It is expected to grow at 9% a year through 1997, when it will stand at $1.5 billion.

In terms of product categories, electrochemical instruments represent the most mature products in the industry. They generated sales of $205 million in 1987, or 7% of the total market. The segment is expected to grow 6.6% a year to $390 million by 1997.

Instrumentation for chromatography achieved sales of $424 million in 1987, or 14% of the total market. Newer applications such as liquid and super-critical fluid chromatography are expected to boost growth to 6.5% a year through 1997, with sales reaching $795 million.

Hyphenated instruments, the smallest yet fastest-growing segment in the analytical instruments market, offer speeds and conveniences that make them attractive to nearly all labs. The segment reached an estimated $148 million in 1987, growing almost 20% a year since 1982. A market totaling $515 million in sales is forecast by 1997.

Optical spectrometers, the second fastest-growing segment, generated 1987 sales estimated at $485 million. Future growth, particularly from Fourier transform infrared spectrometers and fluorescent spectrometers, should produce sales of over $1 billion in 1997.

Components and parts are starting to generate substantial sales as well - they reached $320 million last year and FIND/SVP projects growth of nearly 11% a year through 1997, when the segment will reach the $900 million level. Other instruments, such as thermal analysis equipment and clinical laboratory instruments, will round off the market, reaching sales of nearly $2.6 billion by 1997.

Imports, exports of instruments for physical or chemical analysis

	Imports	Exports
1986	274,315	936,682
1987	346,989	1,145,281
1987 (Jan-Jun)	152,276	533,965
1988 (Jan-Jun)	197,290	673,071
% change 87-88	30	26

Values - $1,000 source: USITC

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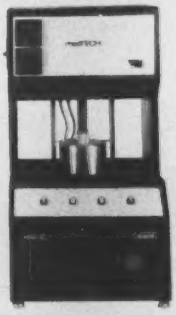

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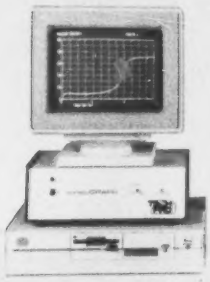

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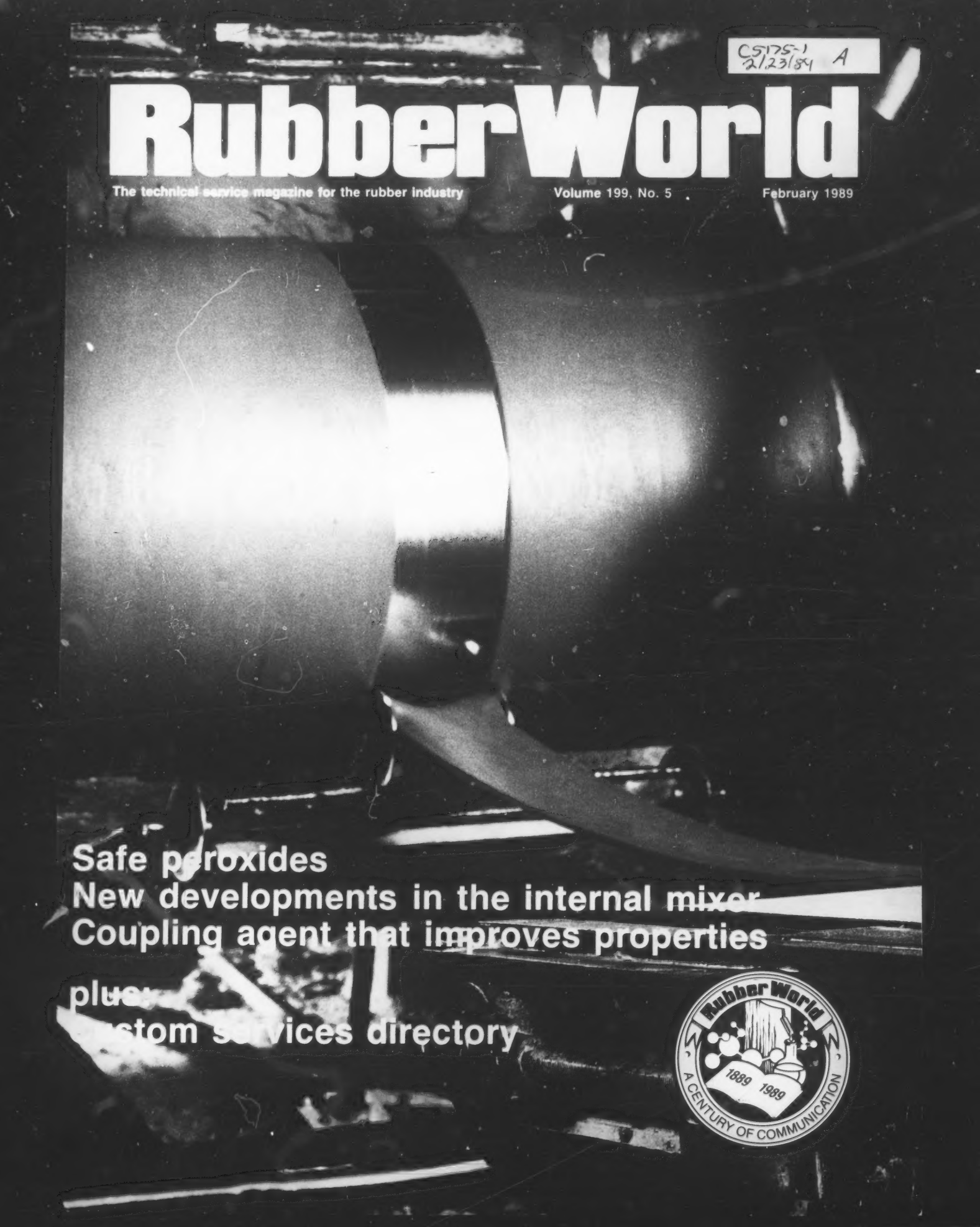
The technical service magazine for the rubber industry

Volume 199, No. 5 February 1989



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1889 1989
A CENTURY OF COMMUNICATION

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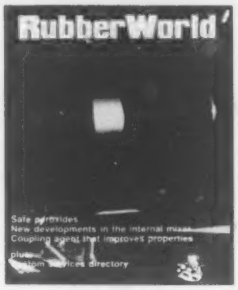

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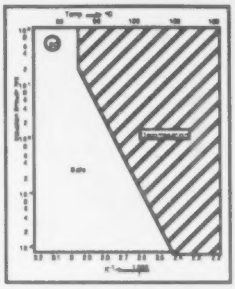

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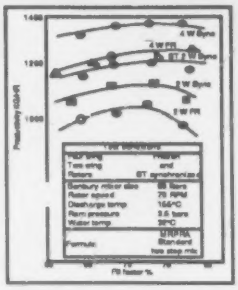

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by Jon Menough, contributing technical service editor. This month's column reviews the action of waxes in protecting rubber.

17 Patent News
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19 Safe peroxides for crosslinking
by J.J. de Groot and A.G. Bollen, Akzo Chemie. The authors make a strong case that safe peroxides can be selected, based upon available knowledge of kinetic parameters.

30 Coupling agent improves properties
by T. Yamaguchi, I. Kurimoto, H. Nagasaki and T. Okita, Sumitomo Chemical Co., Ltd. The authors demonstrate the improvement of dynamic properties of vulcanized rubber by the use of a new additive which eliminates the health problems of nitroso compounds.

34 The internal batch mixer: Recent developments in designs and controls
by Michael A. Melotto, Farrel Corp. This article describes improvements in design with special reference to quality, productivity and new developments.

42 Custom mixing directory
This directory of North American custom mixers of rubber and other rubber custom services suppliers is accompanied by maps showing their locations.

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Cover

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A Lippincott & Peto Publication

Editorial

In seven months this magazine will celebrate its 100th anniversary. Our October 1989 issue of *Rubber World*, the 1201st issue of what began as *India Rubber World and Electrical Trades Review*, will start its second century of publishing. In one of the first business streamlinings, the "and Electrical Trades Review" was dropped in 1900. "India" left the masthead in 1954. No further streamlining of the logo is planned, although our vendors call us RW.

The 1201st issue has been in the planning stages for some time.100th anniversaries are rare, in publishing or any business. Since we haven't found any other magazine's 100th anniversary issue, we're basically breaking new ground. We don't think you should just put out another October issue and call it your 100th anniversary issue.

Part of the planning involves researching the early issues. Reading about the infancy of the rubber industry is entertaining. Technically speaking, the rubber industry today bears little resemblance to the industry in 1889. The evolution is phenomenal. Cautchouc and Gutta Percha compared to TPEs and FKMs.

Publishing however is quite similar. Sure the technology of publishing has changed drastically, but the content of the magazines is fairly similar in scope. The tradition of publishing current technical material to assist the rubber processor and manufacturer has been retained throughout the years.

But the first editor, Henry Pierson, had more obstacles facing him. In an editorial commemorating the third year of publication, Pierson wrote of the start-up of the magazine. He printed: "At the time it was launched... it was a surprise to discover how few persons realized the importance and extent of the business. People generally regarded it as an unimportant little industry, which was confined chiefly to the manufacture of patented specialties, toys, some rubber-lined clothing and principally rubber boots and shoes. There was no source of authority, no definite information that could be obtained anywhere, and rubber manufacturers wore such a cloak of silence and mystery about their business that mankind at large was disposed to regard every rubber factory as something in the nature of an infernal machine which was liable to blow-up and wreck the community at any moment."

I know it makes our job of providing information easier by not having to worry about overcoming such a negative image of the industry. And the fact that your reading this proves that Pierson and those succeeding him had a hand in reversing that image.

Don R. Smith
Editor

RubberWorld

EDITORIAL STAFF

Don R. Smith editor
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Deanne Dodd composition editor
Jon Menough contributing technical service editor

BUSINESS STAFF

Job Lippincott publisher
John W. Peto v.p. sales
Dennis Kennelly sales representative
Barbara Gordon adv. production manager
Jane McBee assistant adv. production manager

EDITORIAL OFFICES

P.O. Box 5485
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- Blue Book: Materials, Compounding Ingredients, and Machinery for Rubber

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Business Briefs

Acquisitions, expansions

Firestone Synthetic Rubber & Latex will increase capacity at its Lake Charles, LA, synthetic rubber plant, and install special polymerization facilities in a $22 million project expected to be completed in early 1990. Expansion will allow for the production of solution styrene butadiene rubber polymers, and involves the installation of an additional polymerization line and streamlining the packaging area in the Lake Charles plant. Capacity of solution synthetic rubber will increase about 12 percent with the planned expansion.

Firestone Industrial Products has reached a tentative agreement to acquire a factory in Williamsburg, KY, for production of air springs for use in the transportation and manufacturing industries.

General Tire is implementing a five-year, $159 million capital investment project that will double radial tire production, and convert current bias technology to radial passenger and light truck tire technology at its Barrie, Ontario, Canada manufacturing facility. Approximately 9,000 tires now are produced daily at the plant.

Johnson Controls has entered into a definitive agreement to purchase interest in **E.A.H. Naue GmbH & Co. KG**, a manufacturer of foam seating, plastic and other components. Naue, headquartered in Espelkamp, West Germany, owns or has equity in companies in West Germany, Austria, England, Yugoslavia, Mexico and Spain. The agreement is subject to approval by the German Cartel Office.

The **Goodyear** and **Pacific Dunlop Ltd.** joint venture, **South Pacific Tyres** will construct a $69 million

RMA rubber report through October
(figures in metric tons)

	YTD 1988	YTD 1987	% chg.
Total new rubber			
New rubber available	2,848,031	2,704,783	5.3
Imports	913,792	900,431	1.5
Exports	479,734	414,854	15.6
Apparent consumption	2,354,034	2,321,489	1.4
Total natural rubber			
Imports	701,692	666,581	5.3
Exports	42,108	29,782	41.4
Apparent consumption	675,174	645,815	4.6
Total synthetic rubber			
Production	1,934,239	1,806,352	7.2
Imports	212,100	233,850	-9.3
Exports	437,626	385,072	13.6
Apparent consumption	1,678,854	1,675,668	.2
Total SBR			
Production	750,465	699,463	7.3
Imports	75,510	67,959	11.1
Exports	161,498	142,130	13.6
Apparent consumption	641,889	646,261	-.7
Total nitrile			
Production	62,857	56,087	12.1
Imports	13,984	13,086	6.9
Exports	12,952	11,126	16.4
Apparent consumption	63,215	56,007	12.9
Polybutadiene			
Production	337,097	306,063	10.1
Imports	65,133	68,466	-4.9
Exports	54,330	51,036	6.4
Apparent consumption	338,396	328,061	3.2
Ethylene-propylene			
Production	221,773	210,775	5.2
Imports	10,933	5,517	98.2
Exports	42,522	38,557	10.3
Apparent consumption	191,232	172,701	10.7
Butyl, polychloroprene, polyisoprene, silicone and other synthetic elastomers			
Production	562,045	531,964	5.6
Imports	46,540	78,822	-41.0
Exports	166,324	142,223	17.0
Apparent consumption	444,120	472,643	-6.0

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Business Briefs

Lydall Elastomers has completed its name change to **Acadia Polymers, Inc.**

Parker Hannifin reported net income of $25.2 million on sales of $613 million for the second quarter of fiscal 1989, ended December 31.

PPG Industries reported fourth quarter net earnings of $102.3 million on sales of $1.4 billion.

Standard Products announced net income was $7.2 million on sales of $131.4 million for the second quarter of its 1989 fiscal year.

Markets, news

The **International Institute of Synthetic Rubber Producers** predicts that worldwide synthetic rubber consumption should reach over 11.5 million metric tons by 1993, according to its long-term worldwide rubber forecast. W.E. Tessmer, managing director of the Institute says total new rubber consumption, including natural rubber, should increase by an average yearly rate of 2% from the 1989 forecast level of 15.6 million metric tons to 17.2 million metric tons in 1993.

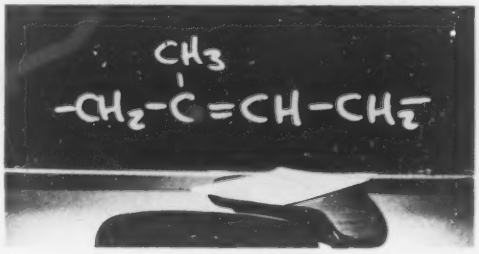
Styrene butadiene rubber consumption, which comprised the largest share of the synthetic rubber market at 34.9% in 1988, will be limited to an increase of 234 thousand metric tons between 1989 and 1993. Carboxylated latex consumption, with 15.4% of the synthetic rubber market, and polybutadiene consumption, with 16.1% of the market, are predicted to remain at that level for the next five years. EPDM consumption projections show the strongest growth with an increase of 18.9% over the 1989 outlook to 642 million metric tons predicted for 1993.

According to the forecast, tire and tire products continue to be the primary end-use category for synthetic rubber, with 42% of the world's synthetic rubber being used in that category.

RMA tire report through October (figures in thousands of units)

Passenger tires	YTD '88	YTD '87	% change
Shipments			
original equipment	45,043	44,969	0.2
radial	38,399	38,156	0.6
replacement	130,148	126,647	2.8
radial	121,796	113,650	7.2
export	7,930	4,814	64.7
radial	7,078	4,205	68.3
total	183,121	176,430	3.8
radial	167,273	156,011	7.2
Production	147,079	140,229	4.9
radial	133,952	123,409	8.5
Truck & bus tires			
Shipments			
original equipment	7,426	6,646	11.7
radial	5,503	4,621	19.1
replacement	28,252	28,835	-2.0
radial	16,605	15,666	6.0
export	2,753	1,686	63.3
radial	2,135	1,201	77.8
total	38,432	37,167	3.4
radial	24,243	21,489	12.8
Production	30,918	29,865	3.5
radial	19,107	16,925	12.9

LOOK AT IT AS JOB INSURANCE



The Rubber Division is dedicated to an idea: For polymer scientists, engineers and technicians, a career is a lifelong learning process.

And today in the broad field of rubber chemistry, the life of the technological information core upon which you base your career is estimated to be less than 5 years.

Where professional advancement is concerned, not to mention improved technical competence or even familiarization with techniques and terms for beginners, the value of the Rubber Division's extensive educational programs is inestimable. (In more than 20 years, some 15,000 people have taken the courses at all levels.)

Devised in cooperation with university professors, there are correspondence and classroom courses in Basic, Intermediate and Advanced Rubber Technology. Also provided are opportunities to attend frequent teaching symposia and workshops, and participants have unlimited access to technical papers.

For more information, write to: Education Committee, Rubber Division, ACS, The University of Akron, Akron, Ohio 44325 or call 216-375-7814 (Telex: 986434)

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The technical service magazine for the rubber industry

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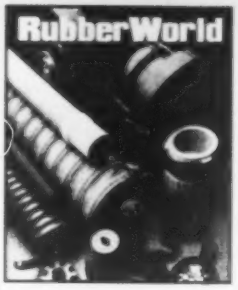

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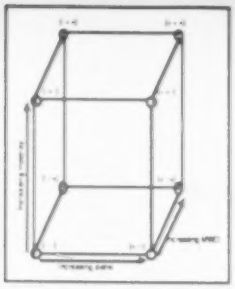

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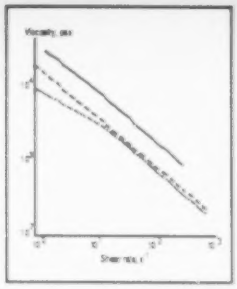

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by Jon Menough, contributing technical service editor. This month's column looks at potential sources of problems in handling carbon blacks, and offers solutions.

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edited by Bob Samples, Akron Rubber Development

16 **Effects of EPDM polymerization variables on properties of olefinic TPEs**
by Robert E. Benefield and Oscar A. Ruiz, Copolymer Rubber & Chemical. The authors present experimental design techniques that are shown to be an integral part of the polymer product development process.

25 **Natural rubber based TPEs**
by Andrew J. Tinker, The Malaysian Rubber Producers' Research Association, Ronald D. Icenogle, Teknor Apex and Ian Whittle, Vitacom Ltd. This article considers the contributions two polymeric constituents make to the properties of the blend, the role of partial dynamic vulcanization in improving properties, and the phase morphology of the blends.

30 **TPUs - the first TPEs**
by Eric C. Ma, Mobay. This article discusses some of the interesting features of TPU in the areas of its block copolymer characteristics, high modulus TPUs and polymer blends.

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A Lippincott & Peto Publication

Editorial

Reading the plethora of magazines devoted to the automotive industry is probably a frightening thing for a rubber product manufacturer. Striving to keep current, anticipate product changes and hopefully gain insight into better positioning the company in the market can turn into a real nightmare. The domestic automakers are looking to foreign outsource parts, the transplant automakers are luring parts manufacturers to the U.S. and the continued replacement of rubber parts with other polymer materials are common themes of editorial articles.

One recent issue of a leading automotive publication ran a two page advertisement that I'm sure quickened the heart rate of many rubber industry people. The left hand page blared in large type "A car without belts?" Situated on the page were three belts that could be construed as forming two eyes and a frown. The right hand page was the sales pitch that began "Open the hood of most cars nowadays and you'll find something missing. The fan belt. But what if you could also get rid of the belt that drives the water pump? The air conditioner? And the alternator?" The company that purchased the ad space (and you don't usually buy two pages of advertising without something specific to sell) went on to tell the reader that they have developed some ideas that could "help these cumbersome devices wind their way into automotive history."

The concept of "beltless cars" as the ad calls them, is not pretty for those manufacturing the belts and their suppliers. It hasn't happened yet but it's being worked on and considerable resources are being put behind this. Unlike the skirmishes fought between elastomers and other polymeric materials for specified status for automotive parts, this battle is not against a plastic trying to move into rubber applications. It's against a technology based on a different electric motor design that would eliminate the belts.

Hopefully the belt suppliers will accept this challenge and will continue product improvements geared to assuring applications in the automotive market. The Rubber Manufacturers Association figures show the automotive v-belt market is near $500 million per year. It's one of the major rubber applications on the automobile, and an application that seemed immune to the onslaught of plastic replacements. Before this ad announcing the new technology, belting seemed assured of a long association with the transportation industry. There's no indication of a major reduction in belt usage by the car manufacturers. But the fan belt is missing from my car. What's next? Hovercraft?

Don R. Smith
Editor

RubberWorld

EDITORIAL STAFF

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- Automotive Polymers & Design
- Blue Book: Materials, Compounding Ingredients, and Machinery for Rubber

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cent. The expansion is scheduled for completion in late 1989 and should be in operation by early 1990.

Precision Roll Grinders has broken ground for a second roll grinding and repair shop to be located in Carrollton, GA. When completed and operational in February, 1990, the 26,000-square-foot plant will provide surface finishing, computer-controlled crowns, special profiles, plating, dynamic balancing, regrooving and repair services for all types of rolls.

RMA rubber report through November (figures in metric tons)

	YTD 1988	YTD 1987	% chg.
Total new rubber			
New rubber available	3,143,816	2,978,506	5.6
Imports	1,007,713	991,210	1.7
Exports	522,832	458,161	14.1
Apparent consumption	2,606,684	2,549,672	2.2
Total natural rubber			
Imports	779,128	730,436	6.7
Exports	46,556	33,282	39.9
Apparent consumption	747,522	706,440	5.8
Total synthetic rubber			
Production	2,136,103	1,989,296	7.5
Imports	228,585	260,774	-12.3
Exports	476,276	424,879	12.1
Apparent consumption	1,859,155	1,843,226	.9
Total SBR			
Production	825,386	772,771	6.8
Imports	82,866	77,417	7.0
Exports	175,100	158,753	10.3
Apparent consumption	714,798	709,474	.8
Total nitrile			
Production	69,422	61,801	12.3
Imports	15,103	14,591	3.5
Exports	13,929	12,384	12.5
Apparent consumption	68,400	61,463	11.3
Polybutadiene			
Production	373,103	338,276	10.3
Imports	70,170	75,095	-6.6
Exports	60,672	55,628	9.1
Apparent consumption	373,785	361,026	3.5
Ethylene-propylene			
Production	243,341	231,458	5.1
Imports	12,778	6,285	103.3
Exports	45,574	43,231	5.4
Apparent consumption	210,976	190,483	10.8
Butyl, polychloroprene, polyisoprene, silicone and other synthetic elastomers			
Production	624,850	582,990	7.2
Imports	47,668	87,386	-45.4
Exports	181,001	154,883	16.95
Apparent consumption	491,195	520,785	-5.7

Monsanto's Sao Jose Dos Campos, Brazil plant for the production of Santoprene thermoplastic rubber recently went on-stream. The plant consists of a manufacturing facility, a quality control laboratory and associated material storage and packaging facilities.

DeSoto opened the recently completed addition to its Elgin, IL plant which offers toll and contract manufacture of resin intermediates and finished coatings in addition to captive manufacture of resins and specialty coatings.

Bekaert, of Zwevegem, Belgium is increasing its shareholding in **TWIL Ltd.** of the United Kingdom. The restructuring will increase Bekaert's shareholding to 60%, with **British Steel plc** holding 40%. **Bridon plc** will exchange its shares in TWIL for 100% ownership of three TWIL subsidiaries, plus cash.

PPG has begun operations at its new 51,200-square-foot reinforcements evaulation center in Shelby, NC. The center consolidates PPG's fiber glass reinforcements applications, testing, statistical and customer liaison operations. Equipment installed includes a sheet molding compound (SMC) machine, an extruder and a pultruder, with plans for installation of a pipe filament winder and cyclic burst tester.

Mainline Industrial Distributors opened a 35,000-square-foot office, warehousing and fabrication facility in the Industrial Land Bank in Milwaukee, WI. The expansion is a 40% increase of floor space for the company, and will accommodate a 40-person staff.

The **Society for the Advancement of Material and Process Engineering** relocated into a new 5,200-square-foot facility in Covina, CA.

Contracts, licenses

Enimont Group Company, Montedipe, and the board of the **China International Trust and Investment Corporation Ltd.** have signed a joint venture to build a polystyrene plant in Hong Kong with an annual capacity of 75,000 tonnes. Investment in the project is $110 million (U.S.) and will make use of Montedipe technology.

General Tire has entered into an agreement with **Hoosier Racing Tire** of Lakeville, IN, effective immediately, to provide for the production and sale of Hoosier brand performance radial passenger and radial light truck tires. The new line of products will be produced at General's Charlotte, NC, Mt. Vernon, IL and Mayfield, KY manufacturing facilities, and is targeted to be available early in the second half of 1989.

Cabot awarded a contract to the Linde Division of **Union Carbide** for 18,000 cubic feet per hour of gaseous nitrogen to be produced by the Pressure Swing Adsorption (PSA) air separation process. The plant will be built for Cabot's Cab-O-Sil Division in Tuscola, IL. Anticipated start-up is the second quarter of 1989. Purity of the nitrogen gas produced will be 99.5 percent.

CS175-1
4/25/89 A

RubberWorld

The technical service magazine for the rubber industry

Volume 200, No. 1 April 1989

Tread compounds with surface treated particulate

Using magnesium silicate

Short fiber rubber composites

Tank track observations

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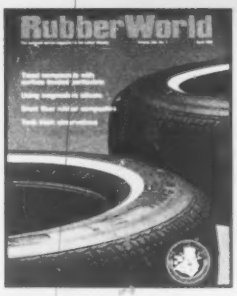
Vol. 200, No. 1/April 1989



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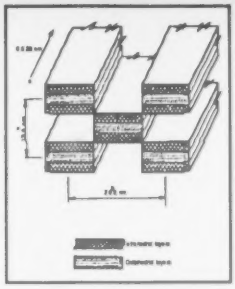

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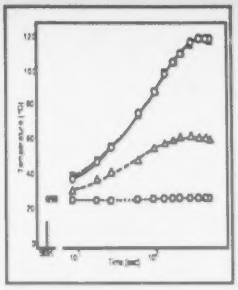

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12 Tech Service: Effective experimentation
by Jon Menough, contributing technical service editor. This month's column looks at the development of test programs that will adequately exercise the variables in a formula to determine optimum function.

14 Patent News
edited by Bob Samples, Akron Rubber Development.

16 Tread compounds containing high concentrations of surface treated particulate
by John Stark, Rubber Research Elastomerics. The author makes a strong case that present technology makes possible the reuse of tire rubber without loss of performance.

23 Using magnesium silicate as a filler
by D.S. Ogunniyi, University of Ilorin, Nigeria. The unique properties achievable with this inorganic filler, having needle-shaped particles, are described.

28 Stress decay and surface temperature distribution of short fiber-rubber composites under dynamic fatigue
by S. Mashimo, N. Nakajima, T. Noguchi, Y. Yamaguchi, Mitsuboshi Belting and M. Ashida, Kobe University. The authors show that significant differences in results of fatigue experiments occur depending on whether the applied deformation is parallel to, or perpendicular to, the main axis of the fibers.

31 Field observations on rubber tank tracks
by C.G. Pergantis, T. Murray, J.L. Mead, R.J. Shuford and A.L. Alesi, U.S. Army Materials Technology Laboratory. Infrared thermography was found to be a useful tool in relating the surface temperature of tank treads to operating variables, which are difficult to quantify in an ongoing effort to increase service life.

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New equipment, instruments, CAD/CAM, products and materials

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Cover

Cover photo courtesy of J.M. Huber Corp., Clay Division.

A Lippincott & Peto Publication

The Audit Bureau

Editorial

The annual Society of Automotive Engineers conference and exposition is really something to behold. Techno-glitz is how one attendee explained this combination of a high quality meeting of engineers with the automotive industry vendors and those wishing to be vendors. The technical portion of the meeting is top notch.The diversity in the over 700 technical presentations can keep you busy all week, even if your interests are limited in scope. Many vendors coordinate exhibits with their technical presentations.

But techno-glitz really applies to the exhibition alone. Cobo Hall in Detroit is turned into a carnival. This past year over 230,000 square feet of this continually-expanding building were used to exhibit the wares of approximately 620 original equipment vendors; Aisle upon aisle of lights, sounds, entertainment and whatever else deemed necessary to attract attention. And high-tech video and electronic systems are a part of many of the booths, if they can be called that anymore. Robots, laser shows and multi-media productions are used to sell engine mounts. Some companys could probably put a serious dent in the national debt with the money spent on their exhibits.

But this show was definitely not one of flash and no substance. Most of the exhibits were very informative. Exhibitors did an exemplary job of displaying their products and providing information about their capabilities. Most exhibitors had their technical people available.

The rubber industry was well represented here, and it was good to see some new exhibitors from our industry, because this is the venue where rubber and its competitors are on public display. It's no secret that plastic resin suppliers and parts manufacturers are aggressively wooing the automotive design engineer to specify plastic. And this was in evidence at the SAE show as they displayed numerous prototype parts that are presently made out of elastomers. In years past, it seemed as if the rubber industry wasn't taking this threat seriously. But the last two shows have seen a marked increase in visibility of rubber product manufacturers and materials suppliers. And the advancement of rubber technology is evident in many of the displays. Thermoplastic elastomers and highly saturated nitriles are just two material areas drawing a lot of attention from the automakers. It's good to see the industry on the offensive in maintaining existing markets and attempting to increase usage, because the plastic people will gladly move in. Those in the steel industry laughed off plastics just a few short years ago.

Don R. Smith
Editor

RubberWorld

EDITORIAL STAFF

Don R. Smith editor
Dr. Walter C. Warner technical editor
Jill Wrigley managing editor
Julie Wagner associate editor
Deanne Dodd composition editor
Jon Menough contributing technical service editor

BUSINESS STAFF

Job Lippincott publisher
John W. Peto v.p. sales
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Barbara Gordon adv. production manager
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EDITORIAL OFFICES

P.O. Box 5485
1867 W. Market Street
Akron, Ohio 44313
(216) 864-2122
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Business Briefs

Acquisitions, expansions

Mark IV Industries has entered into a definitive agreement providing for the sale of **Copolymer Rubber and Chemical**, a wholly-owned subsidiary, to **Naamloze Venootschap DSM**, headquartered in The Netherlands, for cash of $242.5 million plus other considerations. Copolymer will retain its identity and will operate as a subsidiary of DSM.

Nippon Zeon, Tokyo, Japan, has reached a tentative agreement with **BP Chemicals**, London, England, for the purchase of BP's Nitrile Rubber Division, Barry, Wales. Nippon Zeon will convert the facility into a new company, Zeon Chemicals Europe, with capitalization of $8 million.

Zeon Chemicals, the American subsidiary of Nippon Zeon of Tokyo, has broken ground for a $20 million plant for production of Zetpol synthetic rubber, which will occupy a 34-acre tract in Pasadena, TX. Target date for completion is March 1990.

Canadian-based **Polysar Limited's** $25 million Tornac rubber plant, located in the Polysar Gulf Coast complex, went on stream in Orange, Texas. The plant has a 1,600 metric ton capacity.

Dexco Polymers has broken ground in Plaquemine, LA, for a styrenic block copolymer manufacturing plant with an anticipated capacity of 70 million pounds per year. It is scheduled to be on-stream in 1990.

Phoenix Medical Technology has begun production of latex patient examination gloves from a $7.5 million state-of-the-art production line in Andrews, SC. New equipment, featuring advanced process control, will result in capacity of approximately 250 million gloves per year.

Pennwalt, USA and **Akzo Chemical BV**, The Netherlands, have reached an agreement for the transfer of ownership of **Pennwalt Italia spA** to Akzo, for undisclosed terms.

Mobay's Polyurethane Division is building a multimillion dollar facility in New Martinsville, WV for the production of aromatic amine-terminated polyethers which are combined with an isocyanate to form polyurea systems. Construction began in mid-1988 and is expected to be completed in June of 1989, with an initial annual capacity of 10 million pounds. An existing production facility in New Martinsville is being upgraded to expand the company's line of MDI isocyanates.

The $2 million **L.C. Klenk Center for Design, Development & Testing** has been completed in Weatherford, TX, and will focus on application development of high performance compounds and products for the automotive, appliance, construction, electronic and medical industries. The center was developed by **JMK International**, and its subsidiaries **JAMAK Fabrication, Automotive Design Services, JAMAK Europe, K & M Plastics** and **International Component Manufacturing**.

Dutch chemical group **DSM** will build a second melamine plant in Geleen, The Netherlands at an estimated cost of Dfl. 150 mil. It is scheduled to go on stream in 1991.

Goodyear will invest $5.2 million for expansion of the Polyester Research & Development Center in Akron, OH. Set for completion by November 1989, expansion includes a 17,000 sq. ft. addition to the west end of the center, and the addition of commercial scale processing equipment.

M.A. Hanna has acquired **Bruck Plastics** of Chicago, IL, which maintains six distribution outlets in the Mid-

RMA 1988 rubber report
(figures in metric tons)

	1988	1987	% chg.
Total new rubber			
New rubber available	3,426,480	3,275,262	4.6%
Imports	1,101,617	1,093,145	.8%
Exports	570,214	491,005	16.1%
Apparent consumption	2,819,176	2,793,137	1.0%
Total natural rubber			
Imports	853,862	810,824	5.3%
Exports	54,924	36,996	48.5%
Apparent consumption	810,771	775,819	4.5%
Total synthetic rubber			
Production	2,324,863	2,184,117	6.5%
Imports	247,755	282,321	-12.2%
Exports	515,290	454,009	13.5%
Apparent consumption	2,009,637	2,017,311	-.4%
Total SBR			
Production	899,626	850,364	5.8%
Imports	91,456	83,277	9.8%
Exports	189,097	172,114	9.9%
Apparent consumption	770,860	770,811	0
Total nitrile			
Production	76,294	68,542	11.3
Imports	16,579	16,175	2.5
Exports	15,065	13,369	12.7
Apparent consumption	73,676	68,061	8.2
Polybutadiene			
Production	407,178	371,349	9.6%
Imports	75,239	81,964	-8.2%
Exports	66,993	60,816	10.2%
Apparent consumption	406,049	394,449	2.9%
Ethylene-propylene			
Production	263,089	254,060	3.6%
Imports	15,307	7,138	114.4%
Exports	47,908	47,228	1.4%
Apparent consumption	229,820	208,885	10.0%
Butyl, polychloroprene, polyisoprene, silicone and other synthetic elastomers			
Production	678,674	637,802	6.4%
Imports	49,174	93,767	-47.6%
Exports	196,227	160,482	22.3%
Apparent consumption	529,229	575,109	-8.0%

Business Briefs

single ply by the end of 1989, and 68.7 percent by the end of 1990, according to an industry spokesman.

In a measure aimed at maintaining service to members, the United Rubber Workers (URW) International Executive Board approved the streamlining of URW districts, decreasing the number from seven to five. Headquarters of the five new districts will be: District 1 - Akron, OH; District 2 - Trenton, NJ; District 3 - Oklahoma City, OK; District 6 - Toronto, Ontario, Canada; and District 8 headquarters is near Nashville, TN.

Air Products and Chemicals increased list and off-list prices of Dabco amine catalysts and metal-based catalysts, Dabco DC surfactants, Polycat 8 catalyst and LK surfactants, by three to ten percent, effective April 1.

Bridgestone reorganized its replacement tire business geographically, establishing four regions - North America, Europe, Asia and a group comprised of Central and South America, Oceania, the Middle East and Africa. In addition, the Original Equipment Tire Division will handle original equipment tire business worldwide.

General Tire increased prices of replacement tires, including tires for passenger and off-road vehicles, light and medium trucks, small and large farm and industrial vehicles, at a range from 3 to 5 percent effective April 1. The company increased radial tire lines by 3 to 5 percent and bias-constructed tires from 3 to 3.5 percent.

1988 RMA tire report
(figures in thousands of units)

Passenger tires	YTD '88	YTD '87	% change
Shipments			
original equipment	54,131	52,913	2.3
radial	46,260	44,988	2.8
replacement	155,292	151,892	2.2
radial	145,578	137,048	6.2
export	9,365	5,987	56.4
radial	8,383	5,215	60.8
total	218,788	210,792	3.8
radial	200,221	187,251	6.9
Production	174,341	167,522	4.1
radial	159,202	147,825	7.7
Truck & bus tires			
Shipments			
original equipment	8,801	7,845	12.2
radial	6,639	5,495	20.8
replacement	33,918	34,514	-1.7
radial	20,208	19,000	6.4
export	3,301	2,069	59.5
radial	2,550	1,483	72.0
total	46,020	44,428	3.6
radial	29,398	25,977	13.2
Production	37,010	35,455	4.4
radial	23,055	20,176	14.3

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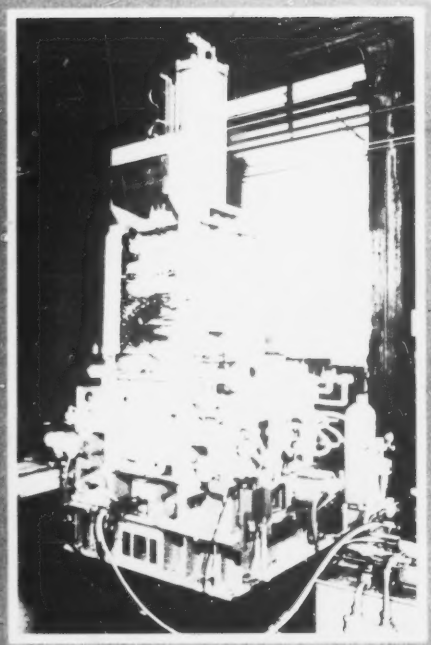
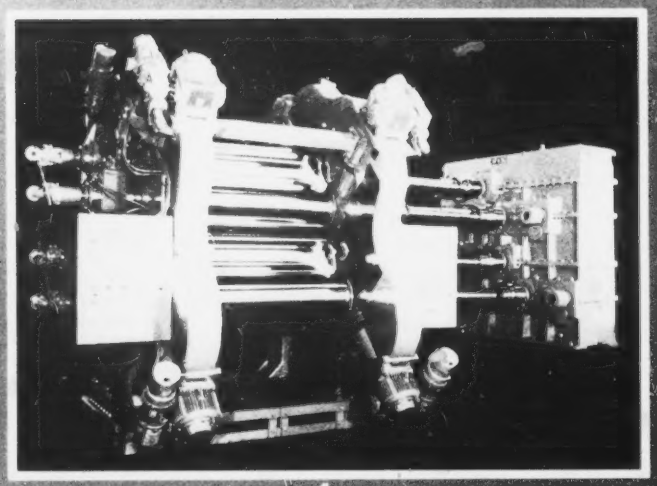
Rubber World

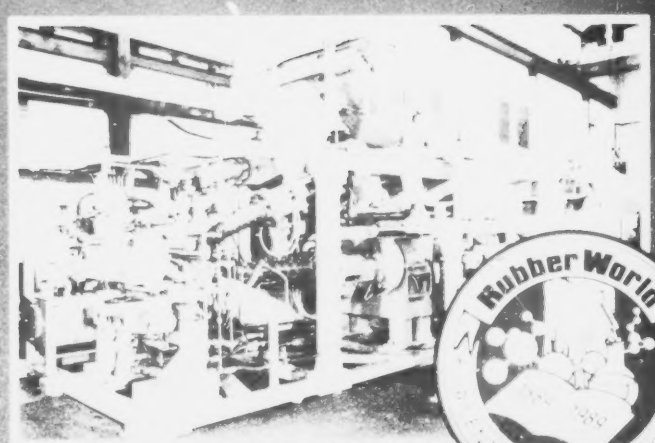
The Technical Service Magazine for the Rubber Industry Volume 200, No. 4 July 1989





Annual Machinery & Equipment Issue

Injection molding TPEs — Improving calendering
Evaluating an intermeshing rotor internal mixer
Compounding for rolls — Corporate Profile '89



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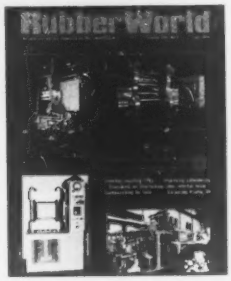
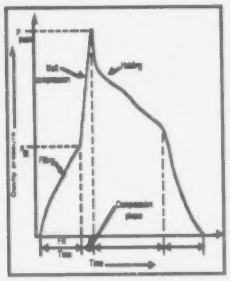


Machinery & equipment



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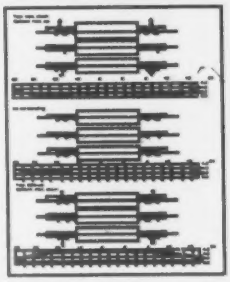

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12 Tech Service: Predicting toughness
by Jon Menough, contributing technical service editor. This month's column reviews the paper "Dynamic and mechanical analysis of track pad elastomers before and after service," presented at last fall's Rubber Division meeting by John Vicic, FMC Corporate Development Center.

14 Injection molding thermoplastic elastomers
by John A. Hudson, Boston Scientific Corp. The author presents guidelines for injection molding styrenics, polyolefins, copolyesters, polyurethanes and polyamides.

18 Performance evaluation of an interlocking rotor internal mixer
by J. Batchelor, P.K. Freakley, S.N. Ghafouri and D.W. Southwart, Institute of Polymer Technology and Materials Engineering, Loughborough University, U.K. This article quantifies the influence of six process operation variables on the processability of a carbon black filled natural rubber compound and on mixer responses.

23 Improving calendering operations
by Don Bauman, Pathex, Inc. The author explains how calendered products manufactured can be improved with minimal changes and with correct maintenance and proper operation.

25 Compounding requirements and techniques for rubber covered rolls
by Thomas L. Jablonowski, Uniroyal Chemical Co. This article presents a review of compounding techniques for development of rubber compounds for roll applications, focusing primarily on EPDM and NBR polymers.

32 Machinery sales continue strong
A study of new rubber equipment suppliers is presented, along with results of RW's annual survey of used and rebuilt rubber equipment suppliers. Also included is a directory and a grid showing rebuilding capabilities.

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Editorial

The machinery and equipment segment of the rubber industry appears to be in good shape and if this is a true barometer, the industry as a whole must be increasing production. The sales of rubber processing and auxiliary machinery has always been a tough one to monitor. There isn't an industry association that keeps statistics and the government figures are incomplete and inconclusive because they aren't specific enough. For years we have surveyed this market from the sellers' - the new, used and rebuilt machinery suppliers, viewpoint and from the buyers' - the rubber product manufacturers, viewpoint.

This year's survey of the used and rebuilt machinery suppliers was the most positive ever. Of the 38 respondents, only one company indicated sales were off in 1988 compared to 1987 and only one company (not the same one) indicated that sales this year might not reach last year's mark. This coupled with a report from Business Trend Analysts on new machinery indicates that product manufacturers are investing in equipment. It looks like 1989 could be the third straight year of sales gains for both new and rebuilt equipment dealers. Last year marked the first time in this decade that sales increases were posted two years in a row. Results from both appear on page 32.

We at Rubber World would like extend our best to Marge Bauer and Don Brotzman, both recently retired. Bauer, the executive director of the Rubber Division, oversaw phenomenal growth and managed it expertly throughout her career which spanned three decades. The uniqueness of the Division's mostly volunteer set-up couldn't have made it easier for her, but there was rarely any criticism. And if you know the membership of the Division, that's an exemplary accomplishment. Brotzman served as president of the Rubber Manufacturers Association since 1981and served the industry well. He joined the RMA in 1977 in the midst of the Firestone 500 fiasco and ably handled rubber industry interests in Congress and in front of the regulatory agencies. The industry will miss these two and we would like to thank them for their assistance to us and to the industry. We wish for them, as Spock would say, to live long and prosper.

Don R. Smith
Editor

RubberWorld

EDITORIAL STAFF

Don R. Smith	editor
Dr. Walter C. Warner	technical editor
Jill Wrigley	managing editor
Julie Wagner	associate editor
Deanne Dodd	composition editor
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BUSINESS STAFF

Job Lippincott	publisher
John W. Peto	v.p. sales
Dennis Kennelly	sales representative
Barbara Gordon	adv. production manager
Sally Dowling	assistant adv. production manager

EDITORIAL OFFICES

P.O. Box 5485
1867 W. Market Street
Akron, Ohio 44313
(216) 864-2122
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Business Briefs

Chicago Boiler Co., CB Mills Division, appointed **Gerlach Industrial Sales** as representatives, responsible for the sales, service and promotion of vertical sand mills and horizontal media mills, in New Jersey, Eastern Pennsylvania, Delaware and New York.

Corporate, financial news

Akzo increased prices 5% for all grades of Trigonox EHP and Trigonox SBP peroxydicarbonate initiators. New delivered prices for orders of 500 lbs. or more become: Trigonox EHP-B75, $3.58/lb.; EHP-C75, $3.58/lb.; EHP-C70, $3.34/lb.; EHP-C40, $2.14/lb.; SBP, $5.44/lb.; SBP-C60, $3.58/lb.; SBP-C50, $2.98/lb.; SBP-C30, $1.88/lb. Akzo also increased prices of vanadium oxytrichloride for all shipments by $1.75 per pound, bringing the new list price for bulk and C-250 cylinder (3,000 pound) shipments to $7.30 and $7.55 per pound respectively.

Battelle Memorial Institute reported total revenues of $597 million from worldwide operations in 1988.

Bridgestone (U.S.A.) and parent company **Bridgestone Corp.** formally dedicated the site of its new U.S. radial truck tire plant in Warren County, TN. Bridgestone (U.S.A) also announced general price increases on its passenger, light truck, truck and bus, off-the-road, kart, agricultural and industrial tires, ranging from three to six percent, effective July 1.

Carlisle Companies recorded net earnings of $6.1 million on net sales of $143.1 million for the first quarter of 1989.

Degussa Group announced a turnover for the first half of the year of $6.9 million DM.

DSM reported first quarter sales in 1989 of Dfl. 2.8 billion and achieved an operating result of Dfl. 423 million.

GenCorp Automotive is reviewing alternatives to restructure its Toledo, Ohio-based automotive vinyl business because of a continuing industry-wide decline in demand and replacement of vinyl coated fabrics by the automotive industry, and a greater use of cloth, carpet and hard plastics and the gradual reduction in use of exterior landau vinyl.

GE Plastics dedicated its 96,000 sq. ft. Polymer Processing Development Center in Pittsfield, MA, in June.

Hoechst Celanese reorganized its corporate structure into five major business groups: Advanced materials, Advanced Technology, Chemicals, Fibers and Film, and Life Sciences.

Michelin Aircraft Tire Corp. (MATC) is moving its headquarters and R&D operations to Charlotte, NC, from Akron, OH, and will build a new headquarters facility and research center, expected to be operational by August of 1990. It will employ about 70 people.

Park-Ohio reported first quarter sales totaling $35.9 million and income from continuing operations of $558 thousand.

Polysar increased prices of nitrile rubber, excluding Tornac, by 10¢/lb. for medium grades and a minimum of 10¢/lb. for specialty grade products; polybutadiene rubber increased 3¢/lb., except for specialties which increased 5¢/lb.; and butyl rubber prices increased 7¢/lb. for Polysar Butyl 301 and 5¢/lb. for specialty and halobutyl rubber.

Wean Industries is filling an order, valued in excess of $1.5 million, for two twin breakdown mills and two twin final mills used in the manufacture of rubber stock for tire tread, to be installed in a new radial truck tire plant **Bridgestone** is building in Warren County, TN. The equipment is scheduled for delivery early in 1990.

RMA tire report - March
(figures in thousands of units)

Passenger tires	YTD '89	YTD '88	% change
Shipments			
original equipment	14,097	13,312	5.9
radial	12,286	11,337	8.4
replacement	34,128	34,184	-0.2
radial	32,294	31,859	1.4
export	3,435	2,625	30.8
radial	3,163	2,307	37.1
total	51,661	50,121	3.1
radial	47,742	45,503	4.9
Production	46,431	45,152	2.8
radial	43,017	40,732	5.6
Truck & bus tires			
Shipments			
original equipment	2,305	2,226	3.6
radial	1,907	1,633	16.8
replacement	8,342	7,861	6.1
radial	4,781	4,545	5.2
export	935	867	7.8
radial	702	683	2.8
total	11,583	10,955	5.7
radial	7,390	6,861	7.7
Production	10,285	9,525	8.0
radial	6,714	5,709	17.6

laboratory and consulting services for the rubber industry

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Machinery sales continue strong

The machinery suppliers to the rubber industry appear headed for their third straight year of sales increases. Results from *Rubber World's* annual survey of used and rebuilt machinery dealers coupled with a recently released study by Business Trend Analysts indicate the markets for new machinery as well as used and rebuilt should continue strong through the end of this year.

The BTA study, "The markets for plastics working and rubber working machinery," pegged the growth of sales for new rubber working machinery at 8% during 1987 and predicted that 1988 figures would increase 4.9% to $170.6 million. BTA, a Long Island, NY based market research firm, indicated that this would mark the first set of back-to-back yearly gains for the industry since the late 1970s.

Many times a sustained period of growth in sales of new equipment indicates a drop off in interest in used machinery, but *RWs* survey shows differently. 85% of the respondents indicated that sales increased in 1988 with 75% stating they expect further increases to be posted this year. Less than 3% said sales declined in 1988 and the same number predicted a decline for 1989.

Most of the suppliers of rebuilt machinery said there was strong demand for all rubber processing machinery. Presses, mixers, mills and extruders are the most requested pieces and the suppliers indicate that most equipment can readily be had with the exception of cold feed extruders and certain size presses.

Reflecting the capacity increases of the tire industry, the BTA report shows tire building machines accounting for one-third of sales of rubber machinery. Sales for tire building equipment should have reached $55.7 million in 1988, according to BTA. Sales in 1987 were $53.8 million. Tire-building equipment sales accounted for only 21% of machinery sales in 1977. Tire equipment sales have been a third of total rubber equip-

Figure 1 - sales of new rubber machinery ($ millions)

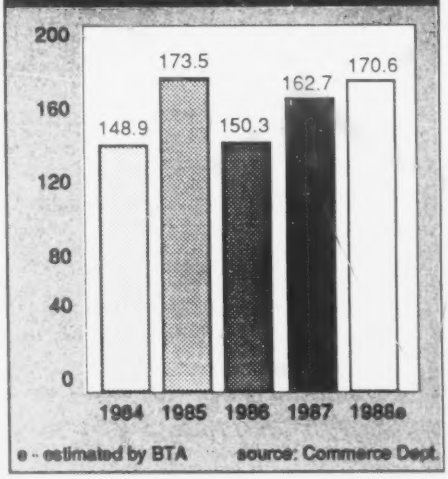


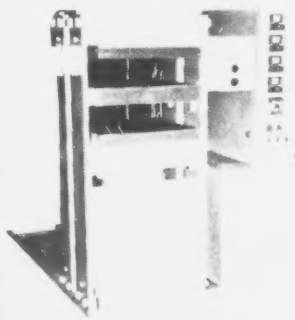
Table 1 - sales of new rubber machinery by type ($ millions)

	1972	*1977*	*1982*	*1987*	*1988e*
High-intensity solids mixers	*	8.5	9.2	10.1	11.3
Extruding machines	40.6	34.2	14.9	16.1	17.2
Tire-building equipment	21.6	34.0	60.0	53.8	55.7
Tire recapping and repairing machinery and equipment	11.9	11.1	29.0	22.3	23.5
Other rubberworking machinery, including calendering machines and vulcanizing presses	56.8	60.6	42.5	37.4	39.2
Parts for rubberworking machinery	NA	NA	24.5	18.2	19.0
Machinery not specified by kind	6.4	9.7	6.9	4.8	4.7
Total	$137.3	$158.1	$187.0	$162.7	$170.6

* - Included in "Other rubberworking machinery"
e - estimated by Business Trend Analysts
NA - Not avaliable

source: US Dept. of Commerce

— *INTRODUCING* —
ECONOMY LABORATORY PRESSES



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ment sales for the last six years.

High intensity solid mixers are currently the fastest growing product category, increasing nearly 12% in 1988 to sales of $11.3 million. These mixers have shown a steady increase in growth since 1977.

Sales of extruders increased slightly last year, BTA estimates, to $17.2 million, which is almost half of what sales were in 1977 when sales reached $34.2 million. Imports of extrusion machines have been running high along with certain types of presses. The Society of the Plastics Industry petitioned the International Trade Commission to look into what they feel is dumping of injection molding machines.

Exports are still a strong part of the rebuilt market, as almost 90% of the rebuilders in the *RW* survey indicated they export rubber equipment. The average is 15.5% of the business, but three companies, Akron Tire Engineering and Machinery, Soberay and West Coast Rubber Machinery, bring the percentage up as exports account for 90%, 60% and 40% of their business respectively. Removing these three brings export sales down just under 10% for the rebuilders.

As in prior years, a directory of used and rebuilt rubber machinery suppliers follows, along with a grid on the capabilities of those companies that offer rebuilding services on pages 36 and 37.

Used, rebuilt machinery suppliers

The following directory lists the suppliers of used and rebuilt machinery to the rubber industry, with address, contact person and type(s) of machinery offered. Rebuilding capabilities are listed on the following two pages

Aaron Process Equipment Co.
Gerald Cohen
P.O. Box 530
Bensenville, IL 60106-0530
(312) 350-2200
Types of machinery: All types

Akron Tire Eng. & Mach. Co.
Erich Dorfner
Owner
P.O. Box 5397
Akron, OH 44313
(216) 867-8406
Types of machinery: All types

Alkar, Inc.
Jim Broch
President
1347 Middlebury Rd.
Kent, OH 44240
(216) 678-0822
Telefax 216-678-6018
Types of machinery: Rebuilders of all types, including presses, post inflators, mills, tire building presses, internal mixers, calenders, etc.

Armaco Ventures, Inc.
Charles Hall
President & General Manager
1920 S. Main St.
Akron, OH 44301
(216) 773-8218
Types of machinery: All types

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Edwin H. Benz, President
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Providence, RI 02908

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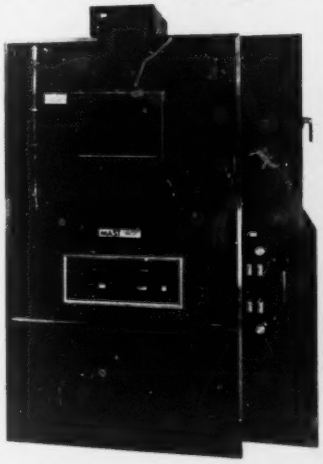

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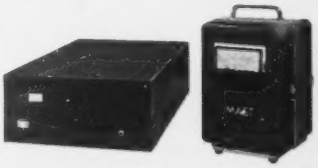

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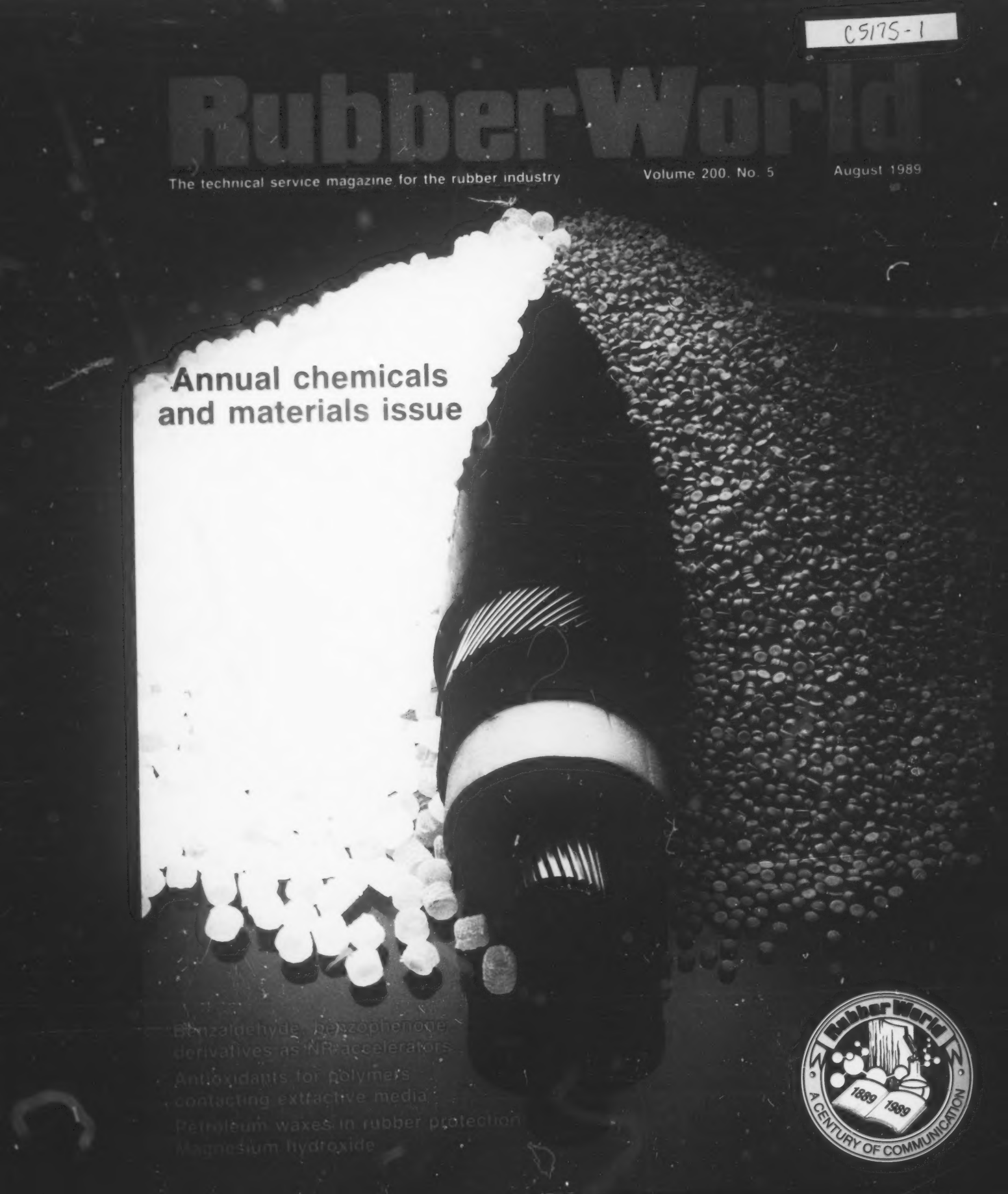
RubberWorld

The technical service magazine for the rubber industry

Volume 200. No. 5 August 1989



Annual chemicals and materials issue

Benzaldehyde, benzophenone derivatives as NR accelerators

Antioxidants for polymers contacting extractive media

Petroleum waxes in rubber protection

Magnesium hydroxide

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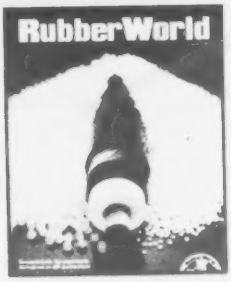
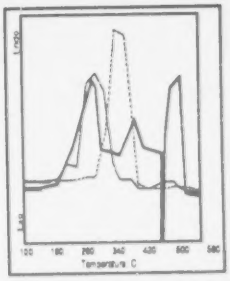


Chemicals & materials



Magnesium hydroxide
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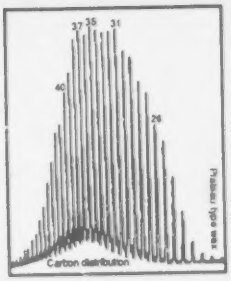

Petroleum waxes p. 36

5 Business Briefs
Acquisitions, expansions; contracts, licenses; corporate, financial news; markets, news.

8 Tech Service: On-stream oil purification lowers operating expenses
by Jon Menough, contributing technical service editor. This month's column reviews the importance of operating machinery only with clean oil.

12 Patent News
edited by Bob Samples, Akron Rubber Development.

13 Persistent antioxidants for polymers contacting extractive media
by Donald E. Miller, Michael M. Gozdiff, Frank G. Shaheen and Paul R. Dean II, Goodyear. The authors compare various non-volatile, reasonably non-extractable commercial materials in NBR and CR.

24 Evaluation of benzaldehyde and benzophenone derivatives as accelerators in NR
by A.A. Yehia, N.L. Doss, National Research Centre, Dokki, Cairo, Egypt, and M.N. Ismail, Military Academy - Heliopolis, Cairo, Egypt. In this study, some organic compounds of the type "aldehyde, ketone-amine condensation products" were synthesized and investigated in NR mixes as accelerators.

30 Magnesium hydroxide: A new and versatile rubber chemical
by Mildred A. Hastbacka, Morton Thiokol, Ventron Division. The magnesium hydroxides studied and recommended as rubber chemicals in references presented in this article are precipitated reaction products.

36 The role of petroleum waxes in the protection of rubber
by F. Jowett, Astor Chemical. This article illustrates how knowledge of the composition of petroleum waxes, and the influence of temperature on their activity, allows rubber waxes to be blended from suitable petroleum raw materials to give products offering maximum protection over a wide temperature range and with optimum cost-effectiveness.

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New equipment, instruments, CAD/CAM, products and materials

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Cover

Cover photo courtesy of Du Pont.

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Editorial

The news that the Society of the Plastics Industry was establishing an automotive market council came as no real surprise. The SPI has always been active in promoting member companies in markets they serve. What is surprising is that there is no similar type of group in the elastomer area. Whereas transportation accounts for around 70% of all elastomers consumed, it is a much smaller market to the plastics industry in terms of percentage. You would think the rubber industry, with its ties to the automotive industry from the inception of the horseless carriage and its heavy dependence on that industry, would already have a council in place.

It's not that the SPI has some radical new idea. The council's mission is to enhance the relationship of the plastics industry with the automotive industry and to create an ongoing and mutually beneficial partnership between the two industries. They plan to:

- provide a means of communications among producers, suppliers and end-users of plastics in the automotive market
- provide a forum for the automotive industry to interact with the plastics industry on current and future needs for parts and materials
- prepare and disseminate educational and promotional material highlighting the qualities and characteristics of plastics as they relate to use in automotive applications
- address the impact of increased use of plastics in automotive applications on health, safety and the environment.

Why doesn't rubber have a similar council with similar aims? This type of group probably falls outside the scope of the Rubber Division, but maybe not the RMA. It might make a perfect subdivision of the Rubber Division, along with the Energy Rubber Group and the Thermoplastic Elastomers Group.

The SPI realizes that the automotive industry is wide open for material replacement and is making sure that design engineers are aware of what plastics have to offer. The makers of rubber parts pretty much go it alone in Detroit and would definitely benefit from a collective effort. After all, many of the major rubber parts manufacturers belong to the SPI, as do the material suppliers. They don't belong to an automotive rubber council because there is no such vehicle.

Don R. Smith
Editor

RubberWorld

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Don R. Smith	editor
Dr. Walter C. Warner	technical editor
Jill Wrigley	managing editor
Julie Wagner	associate editor
Deanna Dodd	composition editor
Jon Menough	contributing technical service editor

BUSINESS STAFF

Job Lippincott	publisher
John W. Peto	v.p. sales
Dennis Kennelly	sales representative
Barbara Gordon	adv. production manager
Sally Dowling	assistant adv. production manager

EDITORIAL OFFICES

P.O. Box 5485
1867 W. Market Street
Akron, Ohio 44313
(216) 864-2122
Telex: 297690 RWMAG UR

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Business Briefs

plant goes on line. Production at the Ireland facility began in June.

Cyclonaire of York, NB substantially upgraded its customer materials testing facility, adding the capability to operate both dilute and dense phase systems, enhanced computerized instrumentation incorporating transducers for data acquisition and the ability to test pumping capabilities for distances in excess of 1,000 feet. Substantial tooling has been added; spare parts storage has been doubled in size; and the electrical and mechanical design engineering departments have been expanded with CAD facilities and state-of-the-art equipment. The company's headquarters, which moved from Henderson to York, will occupy offices with increased space of 30,000 square feet.

Electroserve merged with **Ceast USA**. The company will operate as Ceast USA and will supply rheological, electrical and chemical testing equipment to the North American market.

Elastomer Engineering Inc. (EEI) expanded its Sioux City, IA nylon RIM processing facility with the addition of a Battenfield SHN-65 RIM machine and a full tilting OMS Impianti press with 48" x 40" platens.

Kern Foam Products relocated its headquarters to a 40,000 sq. ft. production facility in South Plainfield, NJ, to produce specialty molded urethane foam products.

Bekaert will build a $28 million (U.S.), 42,000 metric-ton state-of-the-art steel wire manufacturing facility in Shelbyville, KY. Production will consist of low carbon specialty wire to serve preformed staple manufacturers in North America.

RMA tire report - April
(figures in thousands of units)

Passenger tires	YTD '89	YTD '88	% change
Shipments			
original equipment	19,097	18,135	5.3
radial	16,675	15,433	8.0
replacement	46,631	46,109	1.1
radial	44,117	42,964	2.7
export	4,511	3,426	31.7
radial	4,163	2,978	39.8
total	70,240	67,670	3.8
radial	64,954	61,375	5.8
Production	62,255	59,769	4.2
radial	57,792	53,931	7.2
Truck & bus tires			
Shipments			
original equipment	3,075	3,008	2.2
radial	2,538	2,209	14.9
replacement	11,061	10,437	6.0
radial	6,308	6,021	4.8
export	1,243	1,160	7.2
radial	940	911	3.1
total	15,379	14,606	5.3
radial	9,786	9,140	7.1
Production	13,686	12,549	9.1
radial	8,929	7,584	17.7

ESAB AB of Goteborg, Sweden, a producer of welding and cutting products, has reached an agreement to acquire the **L-TEC Group** located in Florence, SC, which manufactures and sells welding and cutting products in the U.S., Canada and Western Europe. L-TEC's trademark, products and distribution channels will be retained and developed.

ESAB Automation will construct a 100,000 square foot office and manufacturing complex in the Loveland/Fort Collins, CO area. The design will allow for a 100,000 square foot expansion in the future. ESAB Automation employs 300 and manufactures and sells automation products.

The **West Company** will construct a 40,000 square foot manufacturing facility in Lititz, PA, for the custom and specialty services unit of the company's Health Care Group, expanding total number of employees to 45. Completion is targeted for 1990.

Dow Chemical relocated its Detroit-based personnel and Automotive Materials Group into expanded facilities. The 28,000 square foot Detroit Dow Center nearly doubles the company's previous square footage and consolidates its automotive-oriented operations and personnel under one roof.

Electronic and Industrial Enterprises purchased a majority share of the joint venture, **Graham Japan Ltd.**, from partner **Carlisle Companies**. The sale includes the execution of a distribution agreement between the new owner and Carlisle's **Memory Products Group**, allowing the continued participation in the Japanese market by the Memory Products Group without the investment.

BFGoodrich Aerospace Division and **Phelps Engineering Plastics** (PEP) have signed a letter of intent for the acquisition of BFGoodrich's Marine Products and Services business unit by PEP for undisclosed terms. The transaction is subject to review by appropriate government agencies and the BFG board of directors, and to the execution of a definitive purchase agreement. Marine Products produces reinforced rubber sonar domes for ships at facilities in Jacksonville, FL.

Contracts, licenses

Freudenberg & Company of Weinheim, West Germany and **NOK Corp.** of Tokyo, Japan, formed **Freudenberg-NOK General Partnership**, which began operations in North America to design and manufacture seals, molded products and vibration control systems. The company operates 24 facilities in North America.

The **Dodge Cork Co.** of Lancaster, PA and **Berleburger Schaumstoffwerk GMBH** of Bad Berleburg, West Germany have formed a joint venture company, **Dodge-Regupol, Inc.**, based in Lancaster, for the manufacture and distribution of a variety of cork, cork/rubber and rubber products. The joint venture company plans to build 90,000 square feet of new facilities.

Business Briefs

The **Automotive Parts & Accessories Assoc.** and **Audits & Surveys, Inc.** have jointly developed the Aftermarket Sales Index (ASI), a research service to assist industry manufacturers in tracking sales of aftermarket products through a base of 2,300 automotive aftermarket chain stores. ASI will be available in January of 1990.

Truflex Rubber Products Company/Pang Rubber Co. of Los Angeles, CA was named sole supplier in the United States and Canada of Goodyear authorized repair materials.

Astor Wax of Harrison, NY, named **G.E. Chaplin** of Flemington, NJ, sales agent for its line of powdered waxes, servicing accounts in Virginia, Maryland, Delaware, New Jersey and Philadelphia, PA. **Washburn-Linder**, Framingham, MA was named sales agent for accounts in New England for Astor Wax.

Carter Baker Enterprises Ltd. of Marshbrook, Shropshire, England appointed **Techema BV** of Rijswijk, Netherlands as agents for its materials testing equipment for the Netherlands, Belgium and Saudi Arabia.

Corporate, financial news

Air Products and Chemicals increased prices of tin-based polyurethane catalysts, effective August 1. Dabco T-9 increased .50¢/lb.; Dabco T-10 increased .25¢/lb.; Dabco T-95 increased .16¢/lb.; and Dabco T-12 increased .35¢/lb.

ASTM's Institute for Standards Research has launched its first project. Submitted by ASTM Committee E-5 on fire standards, the project involves a major international interlaboratory testing program to validate two established and three proposed ASTM fire test methods. **Technical Committee 92** on fire standards will participate in the round robins for the three proposed test methods. Total financial commitment for the project is $1,590,000, of which 95 percent represents the labor and associated costs of the laboratories performing the tests. ISR will raise the remaining $86,000, which will be devoted to the extensive sample preparation and distribution prior to the laboratory tests.

Cabot reported income of $28.1 million and net sales of $540.9 million for the second quarter.

Eagle-Picher reported net income for the second quarter of $13.0 million on sales of $193.1 million.

Goodyear earned a net income of $27.1 million on sales of $2.8 billion for the second quarter. For the first six months of the year, net income was $121.6 million and sales were $5.5 billion.

Mobay achieved net sales of slightly over $2 billion in 1988, and net income of $113.4 million.

Polysar Performance Plastics' Clear Plastics Group renamed the company's clear acrylic copolymer and terpolymer products, dividing them into two groups. Acrylic styrene copolymers are now NAS 10-55 and impact grade acrylic terpolymers are now Zylar 90-92. There are no name changes for P210-D; R-510 resins; and LSC-50 light stable concentrate.

Rockwell International recorded net income of $207.7 million and sales of $3.16 billion for 1989's second quarter.

Rubbermaid reported sales of $334 million and earnings of $28.2 million for the second quarter of 1989. For the first six months of 1989, sales were $683 million and earnings were $57.5 million.

SABIC Marketing Europe is now a wholly-owned affiliate of **SABIC Marketing Ltd.** It will handle all sales of, and customer service for SABIC products in Europe.

UCB Group recorded net sales of BF34.9 billion and profits after tax of 1.4 billion for 1988.

RMA rubber report through March (figures in metric tons)

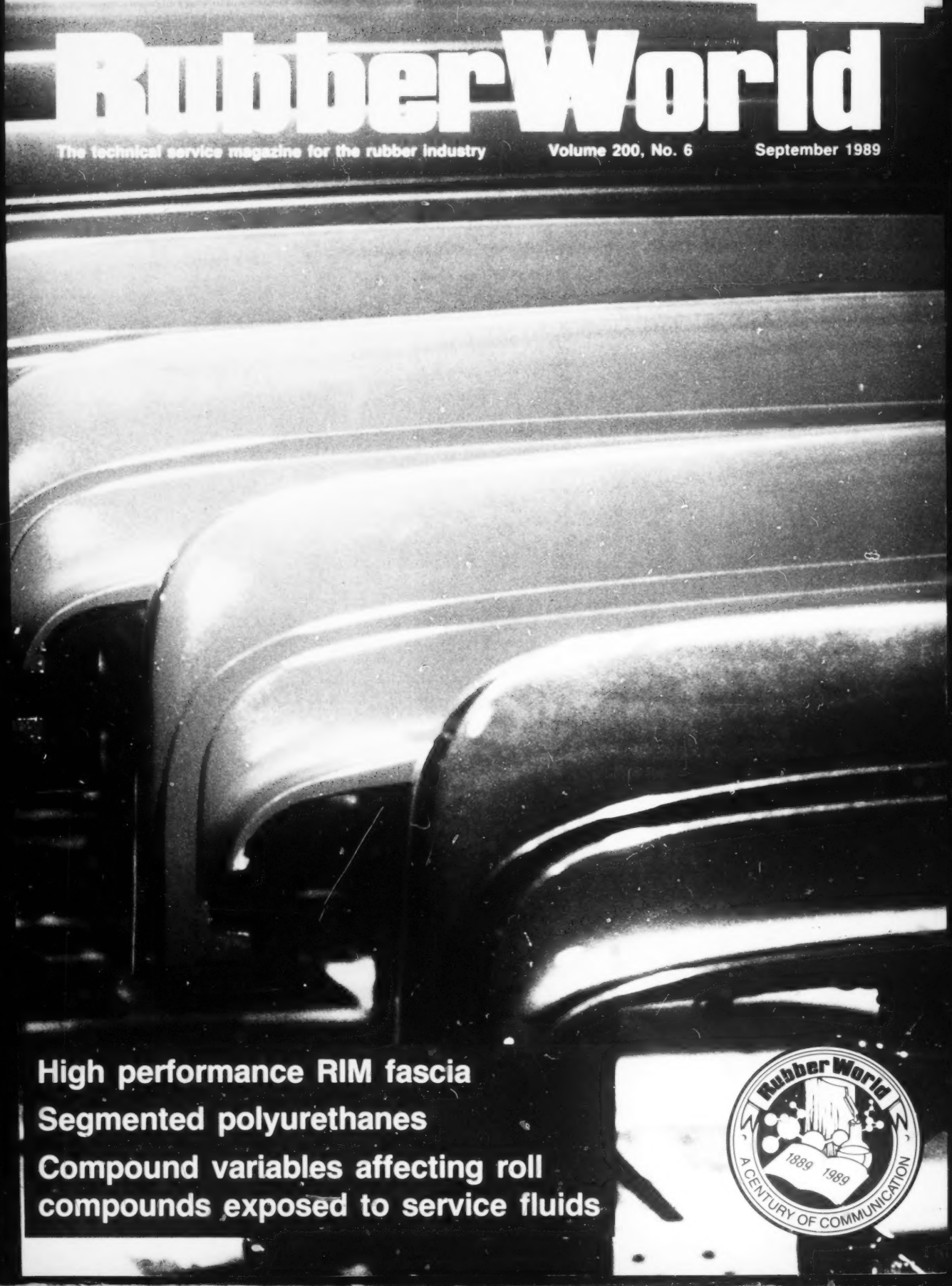
	YTD 1989	YTD 1988	% chg.
Total new rubber			
New rubber available	928,615	883,989	5.1
Imports	341,324	316,710	7.8
Exports	96,857	141,679	-31.7
Apparent consumption	800,915	750,900	6.7
Total natural rubber			
Imports	255,783	239,821	6.7
Exports	10,129	10,363	-2.3
Apparent consumption	229,679	238,752	-3.8
Total synthetic rubber			
Production	587,291	567,279	3.5
Imports	85,541	76,889	11.2
Exports	86,728	131,316	-34.0
Apparent consumption	571,237	512,148	11.5
Total SBR			
Production	223,050	226,114	-1.4
Imports	27,670	22,904	20.8
Exports	18,131	47,044	-61.5
Apparent consumption	224,949	194,221	15.8
Total nitrile			
Production	19,055	18,493	3.0
Imports	2,702	4,300	-37.2
Exports	5,331	4,185	27.4
Apparent consumption	15,644	19,408	-19.4
Polybutadiene			
Production	106,233	98,248	8.1
Imports	19,940	20,167	-1.1
Exports	22,261	18,832	18.2
Apparent consumption	98,137	99,958	-1.8
Ethylene-propylene			
Production	65,017	64,491	.8
Imports	6,031	1,730	254.4
Exports	10,707	14,799	-27.6
Apparent consumption	59,639	54,893	8.6
Butyl, polychloroprene, polyisoprene, silicone and other synthetic elastomers			
Production	173,935	159,932	8.8
Imports	29,098	27,788	4.7
Exports	30,296	46,456	-34.8
Apparent consumption	172,867	143,667	20.3

SEPT

1989

Rubber World

The technical service magazine for the rubber industry Volume 200, No. 6 September 1989



High performance RIM fascia

Segmented polyurethanes

Compound variables affecting roll compounds exposed to service fluids

Rubber World 1889 1989 A CENTURY OF COMMUNICATION

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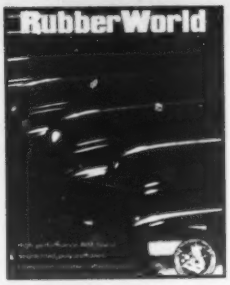
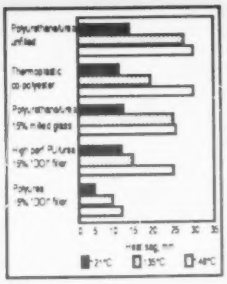


Urethanes



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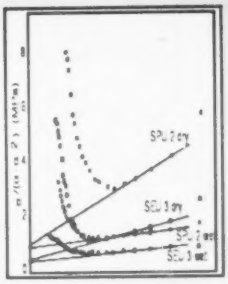

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edited by Bob Samples, Akron Rubber Development.

16 High performance RIM fascia
by James W. Berg, Roy E. Morgan and George A. Klumb, Dow Chemical. The authors present data to show the versatility of polyurethane/polyurea polymers to meet the increasing performance demands of the automotive industry.

21 Segmented polyurethanes based on triblock copolyether as biomedical materials
by Yuko Ikeda, Shinzo Kohjiya and Shinzo Yamashita, Kyoto Institute of Technology, Japan. Introduction of hydrophilic PEO units was found to lessen tendancy for blood-clotting, improve biocompatability, yet retain excellent mechanical properties.

28 Compound variables affecting roll compounds exposed to service fluids
by Gerald Thompson and Steve Strawn, Copolymer Rubber and Chemical Corp. Through a minimal amount of experimentation, the major factors causing undesirable volume swell, shrinkage and weight change in printing rolls have been determined.

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Cover photo courtesy of Dow Automotive Materials Group.

A Lippincott & Peto Publication

The Audit Bureau

Editorial

Education is a hot topic, especially in the urethane industry. But their interest in education goes beyond the traditional school curriculum. They're concerned with educating the American public in general, and specifically their elected officials. The urethane industry has been under siege for quite some time. Shortly after recovering from the MOCA issue along came the link between the use of chlorofluorocarbons and ozone depletion. And as the industry is discovering, other maladies are being laid on their doorstep.

So the industry is banding together through its organizations to go on the offensive - to educate. A letter writing campaign is underway hoping to sway Congress from passing legislation that could severely retard the industry. The Senate, House and the President all are proposing legislation to ease ozone depletion. The bills in Congress call for various regulatory fees and taxes while the Administration is leaning towards an auction of production rights for CFCs or a surcharge for CFC users. All of the proposed legislation would inflict harm on the urethane industry, beyond what the recently approved Montreal Protocol will do. Those manufacturers that use CFCs are urged to write Congress and the President to inform them how the legislation affects your business and to provide examples of environmentally beneficial uses of your product.

Not only do the elected officials have to be educated, but educators have to be educated as well. The Polyurethane Foam Contractors Division of the SPI found this out recently as sprayed polyurethane foam was blamed for illnesses at schools in New York and New Mexico. PFCD staff director George Sievert said further investigation proved that the real culprit was inadequate ventilation, but the sprayed foam industry was unjustly victimized by the news reports containing incorrect information. To hopefully stop the industry from being tarnished in this way again, Sievert has authored an article that ran in *American School & University* magazine detailing the whys of indoor air pollution. He hopes that school administrators, once educated, won't accuse spray foam without evidence, causing a loss of credibility to both the industry and the administrators.

Hopefully these measures will educate other industries to take action before credibility becomes a problem.

Don R. Smith
Editor

RubberWorld

EDITORIAL STAFF

Don R. Smith	editor
Dr. Walter C. Warner	technical editor
Jill Wrigley	managing editor
Julie Wagner	associate editor
Deanne Dodd	composition editor
Jon Menough	contributing technical service editor

BUSINESS STAFF

Job Lippincott	publisher
John W. Peto	v.p. sales
Dennis Kennelly	sales representative
Barbara Gordon	adv. production manager
Sally Dowling	assistant adv. production manager

EDITORIAL OFFICES

P.O. Box 5485
1867 W. Market Street
Akron, Ohio 44313
(216) 864-2122
Telex: 297690 RWMAG UR

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available. Equipment purchases include two seismic reaction masses with 20 x 30 foot bedplates. A central control room for monitoring and controlling tests will be created, and a microprocessor-based controller will be installed.

Arco Chemical began construction on a facility to manufacture conventional and polymer polyols in Fos-sur-Mer, France. The facility will be adjacent to an existing 330 mm lbs./yr. propylene oxide and 790 mm lbs./yr. tertiary butyl alcohol unit, and will have an approximate capacity of 220 mm lbs./yr. The company will also increase PO capacity in Fos-sur-Mer by approximately 110 mm lbs./yr and increase methyl tertiary butyl ether output by approximately 3,000 bbls./day, with start-up targeted for the third quarter of 1990.

DSM Resins U.S. is expanding its production capacity for saturated polyester powder coating resins in Augusta, GA. Phase one, which was recently completed, increased production capacity by 40 percent. Phase two includes the installation of an additional reactor to be operational in 1990. The company is also building a new plant for printing ink resins at the Georgia location. The 10 million lbs./yr. plant is scheduled to come on stream in 1990.

Uniroyal Plastics formed an **Elastomeric Products Division** to concentrate on the custom rubber mixing, specialty calendering, commercial roofing and heavy extrusion markets.

Mobay formed an **Automotive Business Group** to be headquartered in Troy, MI at the company's Automotive Technical Marketing Center. The group will be the focal point for marketing and technical support for all automotive applications of Mobay products.

Ciba-Geigy acquired the epoxy syntactic potting compound aerospace product line of **Products Research & Chemical Corp.**, which will be marketed and sold by the **Furane Aerospace Products** group of Ciba-Geigy.

Hanson Industries' SCM Chemicals unit will increase annual production capacity of titanium dioxide by 58,000 tons, bringing the total to 107,000 tons, at its Ashtabula plant I, in Ohio, at an anticipated cost of $67.5 million. The project includes construction of a second production line and minor changes made to the existing equipment to integrate the two lines. Start-up is set for early 1991.

American Cyanamid will transfer its vulcanized vegetable oils manufacturing operations from Stamford, CT, to its facility in Marietta, OH. The technical staff at Marietta will expand the statistical process control program to include this product line. Marietta is currently being installed with new, up-to-date processing equipment.

RMA tire report - May
(figures in thousands of units)

Passenger tires	YTD '89	YTD '88	% change
Shipments			
original equipment	24,095	23,332	3.3
radial	21,019	19,848	5.9
replacement	59,577	58,972	1.0
radial	56,348	54,947	2.6
export	5,528	4,121	34.1
radial	5,115	3,599	42.1
total	89,200	86,425	3.2
radial	82,482	78,394	5.2
Production	78,031	74,207	5.2
radial	72,553	67,017	8.3
Truck & bus tires			
Shipments			
original equipment	3,884	3,822	1.6
radial	3,213	2,806	14.5
replacement	14,011	13,134	6.7
radial	8,019	7,597	5.6
export	1,546	1,435	7.7
radial	1,160	1,122	3.4
total	19,441	18,391	5.7
radial	12,391	11,525	7.5
Production	16,999	15,514	9.6
radial	11,136	9,411	18.3

Contracts, licenses

Mobay and **First Chemical Corp.** will cooperate on a 250 million lb./yr. aniline plant at Mobay's Baytown, TX, facility. The plant will include nitric acid and nitrobenzene as precursor units. First Chemical will act as general contractor for plant construction and will market all aniline not consumed by Mobay, which will be the owner/operater of the plant, that is expected to be completed in the first half of 1992.

Dow Corning and **Mono-Chem** will work together to formulate and market improved release and lubricant products. Dow will share its silicone technologies with Mono-Chem, which will formulate and market products needed by tire-making plants. Most of the products will be sold under the Mono-Chem name. Dow will continue with direct sales of existing products.

Polymer researchers at **The University of Akron**, Akron, OH, and **Akron Polymer Container Corp.** participated in a joint research venture to create the "Akro," a non-aerosol container. The effort was funded by a $220,000 industrial development loan from Ohio's Thomas Edison Program. Domestic production and distribution of the Akro will be centered in Akron, and its developer, **Robert Winer**, president of Akron Polymer Container, plans to begin licensing the technology of the patented container before the end of the year.

A mutual assistance and cooperation agreement was made between **Hillsdale Tool and Manufacturing**, Hillsdale, MI, and **Fuji Kiko Co., Ltd.**, Tokyo, Japan, for joint development of specific automotive components for the international market.

Dunlop-Enerka and **Akzo**, both Dutch firms, have conducted a program of research into the dynamic behavior of

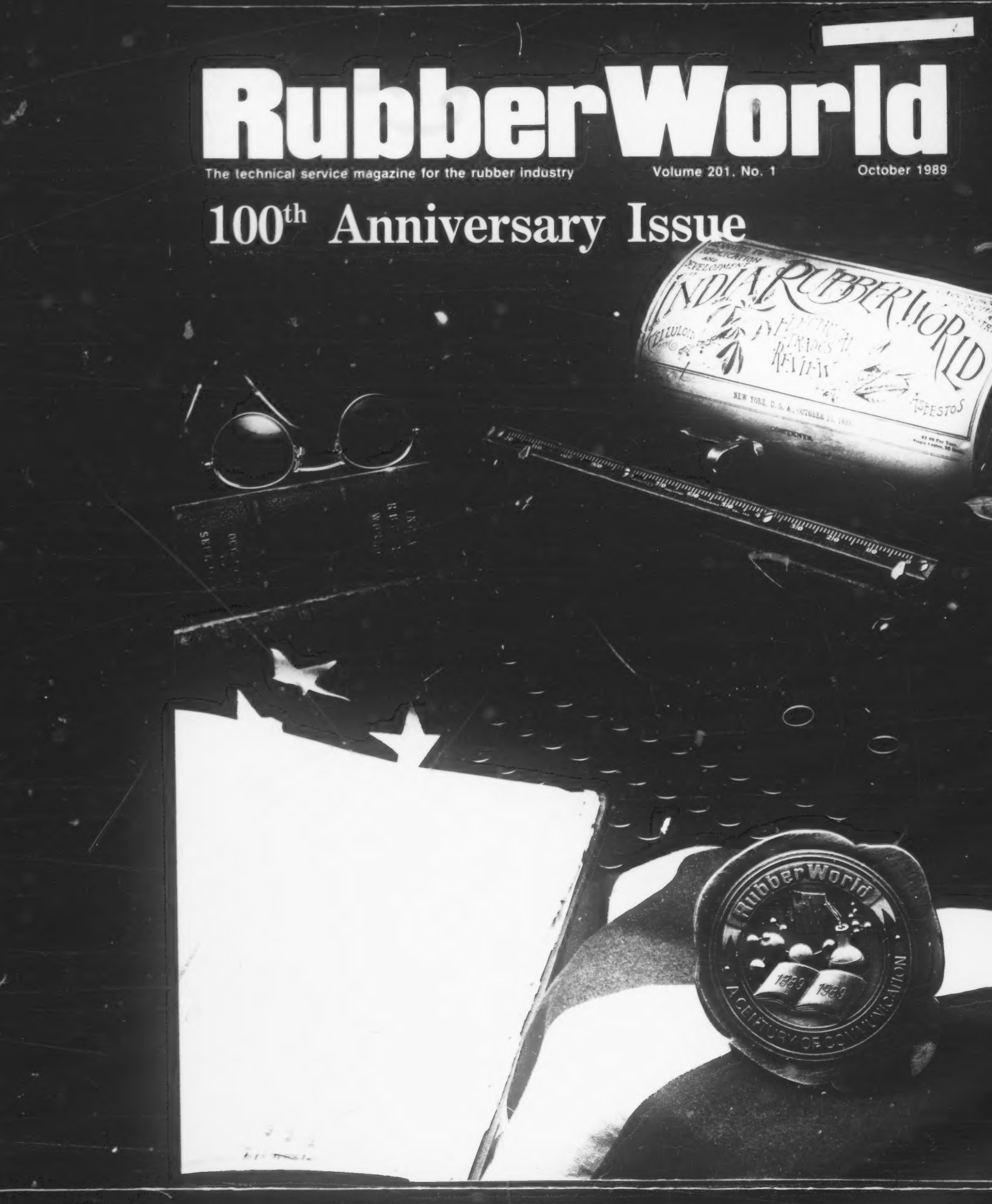
RubberWorld

The technical service magazine for the rubber industry

Volume 201, No. 1

October 1989

100th Anniversary Issue



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A Lippincott & Peto Publication
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The Audit Bureau

Editorial

Researching this issue was quite an eye-opener and on a few occasions a real eye-closer. When planning for this 100th anniversary issue, *Rubber World* had already printed 1,188 issues, of which almost all were perused by the editors. To read of the evolution of this industry on a month-to-month basis is remarkable, because it's not only an account of the progress of a material and an industry, but an account of extraordinary progress of the human species.

Going through those old issues was quite enlightening in other ways as well. In the October 1964 issue we read: "The place attained by these newcomers - the stereo diolefins, EPDM, epoxy rubbers, the urethanes and others still undiscovered - will be more clearly delineated in a subsequent article which will appear in October, 1989." An editor has a lot of nerve to say what's going to be covered 25 years into the future, but we were fearful that if we didn't cover these areas there would be some readers with great memories.

We feel we've covered all bases with contributions from Maurice Morton, John Sommer, Howard Stephens, H.L. Paris, Barbara Davies, Barbara Zimmerman and Dave Ewers, along with our own Walt Warner and Jon Menough. Speaking of covers, the cover of this issue has already won an award for Mayer Advertising. The cover was one of the first items planned for this issue and was actually created a year ago. The photo below shows some of the fine tuning on the cover shot being done by photographer Kim Henderson (left), Leonard Benner (center) the designer and myself.

Don R. Smith
Editor

RubberWorld

EDITORIAL STAFF

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EDITORIAL OFFICES

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1867 W. Market Street
Akron, Ohio 44313
(216) 864-2122
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Business Briefs

The plant will have an initial annual capacity of 30,000 metric tons of tread and carcass grades of carbon black. P.T. Continental also has plans for expansion in the future.

Stamicarbon bv, the licensing subsidiary of **DSM**, and **Hyundai Petrochemical** of Seoul, South Korea signed a contract allowing Stambicarbon to supply technological know how for an LLDPE plant to be built in Korea. Stamicarbon will provide the process design, training and advisory services for the 60,000 t/y plant based on low-pressure solution technology (COMPACT process) expected to come on stream in 1991.

Rogers signed an exclusive licensing agreement with **Polimotor Research** for exclusive rights to the technology of the Polimotor engine for most major markets. Rogers has exclusive rights to produce and sell Polimotor engines in all commercial markets, including the automotive, marine and aircraft industries. Polimotor Research retains the rights to produce and sell Polimotor engines for competition racing and a developmental military diesel program.

Flexfab, Hastings, MI, and **Federal Hose Manufacturing**, Painesville, OH, formed a joint venture agreement to market silicone heater and coolant hose in addition to other silicone and flexible metal hose, ducts and connectors for the trucking and heavy duty equipment markets.

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Circle 8 on card

Newbury Industries appointed **W.A. Bell & Assoc.**, Markham, Ontario, to represent its line of vertical- and horizontal-clamp injection molding machines in all eleven Canadian provinces.

J.M. Huber's Carbon Black Division appointed **Shelan Chemical** as its agent for furnace and thermal blacks in the northeast United States and Canada.

Dexter Adhesives & Structural Materials Division named **Rudolph Bros.** as distributor of Hysol aerospace paste adhesives in W. Virginia, Illinois, Ohio, Indiana, Michigan, Wisconsin, Minnesota and Kentucky.

Neville Chemical appointed **Durr Marketing Associates** as a manufacturer's representative for northwestern Pennsylvania, western New York, and West Virginia.

The Weighing Systems Division of **Sartorius Corp.** appointed **ASC/Aldinger** as an authorized scale dealer for Dallas, TX, and surrounding areas.

Corporate, financial news

Akzo increased prices of Perkacit TMTD from 8 percent to 11 percent; Perkacit TMTM from six to nine percent; Perkacit TETD from six to nine percent and Perkacit DPTT from three to six percent, effective Oct. 1.

Automotive Industries reported third quarter revenues of $12.5 million and a net loss of $3.6 million.

Bekaert Group achieved a consolidated net profit of

RMA tire report - June
(figures in thousands of units)

Passenger tires	YTD '89	YTD '88	% change
Shipments			
original equipment	28,511	28,272	0.8
radial	24,893	24,092	3.3
replacement	74,608	73,925	0.9
radial	70,711	68,905	2.6
export	6,471	4,840	33.7
radial	6,002	4,234	41.8
total	109,589	107,037	2.4
radial	101,605	97,231	4.5
Production	93,070	89,090	4.5
radial	86,646	80,598	7.5
Truck & bus tires			
Shipments			
original equipment	4,598	4,599	-
radial	3,809	3,379	12.7
replacement	17,178	16,228	5.9
radial	9,945	9,382	6.0
export	1,834	1,708	7.3
radial	1,373	1,337	2.7
total	23,610	22,536	4.8
radial	15,126	14,097	7.3
Production	20,273	18,572	9.2
radial	13,347	11,276	18.4

Natural rubber: Still going strong

by Barbara Davies, Malaysian Rubber Producers' Research Association

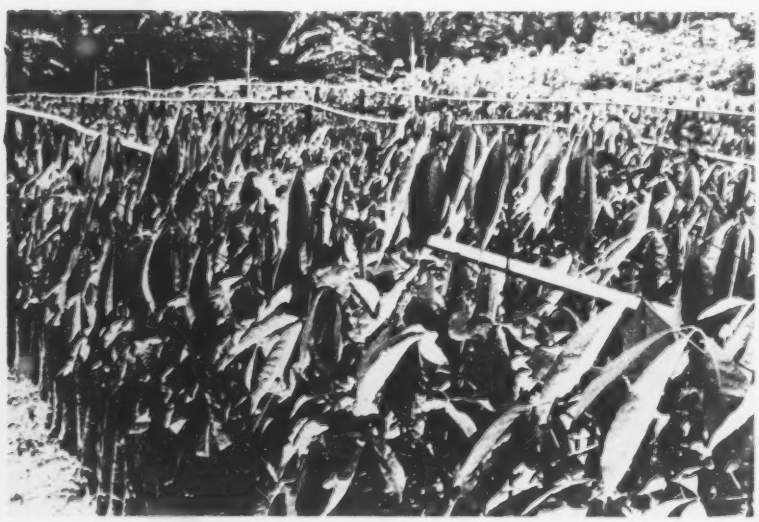
Natural rubber is the only rubber which can boast a history longer than that of *Rubber World*. 'Discovered' by Christopher Columbus in the fifteenth century, it remained a curiosity until 150 years ago when the twin discoveries of mastication and vulcanization established the basis of modern rubber technology. With the growth of rubber cultivation in South East Asia at the turn of the century, associated with the growing demand for tires for the first motor cars, natural rubber became a viable and profitable crop.

For its first five decades, the pages of *Rubber World* would have been filled with developments relating almost exclusively to natural rubber. The second five decades have seen enormous changes, with the advent of commercial synthetic rubbers which now hold 66% of the world market. The turning point came about 40 years ago, when, for various reasons, the share of synthetic rubbers started to climb and the growth of natural rubber production slowed down. In 1962 production of synthetics by the free world overtook that of natural rubber.

That natural rubber is still a vital raw material owes much to considerable advances in the science and technology of both production and end-use over the last 50 years, and to its inherent characteristics which still make it the material of choice in many applications.

Developments in production

The steady growth of natural rubber production from around 1 million tons in the late 1930s to over 5 million tons last year is due not only to the increased hectarage under rubber, but also to agricultural research. The original plantings of Hevea brasiliensis yielded about 250 kg/ha/yr - tree breeding and selection have raised potential yields to well over 3,000 kg/ha/yr. One of the most promising new clones being developed in Malaysia has yielded more than 5,000 kg/ha/yr in the preliminary evaluation stages. The newer clones not only give higher yields but are precocious yielders.



Grafting techniques are used for fast, cost-effective propagation of good planting materials. Such techniques are used successfully in commercial estates and have been introduced in the smallholder sector.

Average yields in the major natural rubber producing countries reflect the different structure of their industries. In the three major producing countries, smallholders predominate, but to different extents. In Malaysia they account for 75% of the industry, in Indonesia 85% and in Thailand 95%. Smallholdings tend to suffer from uneconomic size, low productivity and low capital.

Increased output in Indonesia and Thailand has come mostly from increases in hectarage: in the order of half a million hectares in each country since 1960. Yields have increased from 440 kg/ha/yr in 1970 to 480 kg/ha/yr in 1986 in Indonesia; the equivalent figures in Thailand are 300 kg/ha/yr and 630 kg/ha/yr. In Malaysia, on the other hand, there has been a drop in hectarage, but the average yield has increased from 800 kg/ha/yr in 1970 to over 1,100 kg/ha/yr in 1986, leading to a slight increase in overall production. This difference in productivity between Malaysia and the two other major producers is partly due to the fact that Malaysia was the first to undertake major replanting programs in the 1960s and early 1970s.

Two further important differences exist between Malaysia and the other major producers. Malaysia is the only one of these countries with an integrated system of research, development and advisory services covering both production and consumption aspects of natural rubber. The Malaysian Rubber Research and Development Board (MRRDB) is the parent body which directs and coordinates these activities, including the production research carried out by the Rubber Research Institute of Malaysia in Kuala Lumpur, the consumption orientated work of the Malaysian Rubber Producers' Research Association in the UK, and the Technical Advisory Service to consumers worldwide provided by the Malaysian Rubber Bureau. The second

difference, affecting smallholder productivity, is that in Malaysia over 400,000 hectares of smallholders land is within various organized land schemes. This enables smallholders to adopt modern agro-management practices and benefit from research, good infrastructure and social amenities. Yields in such organized schemes approach those of the estates, in Malaysia around 1,500 kg/ha/yr.

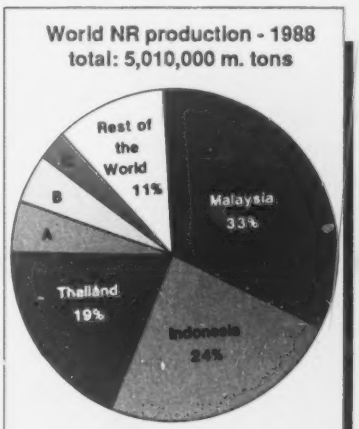
Recently efforts have been made to widen the genetic base of Hevea. The entire production industry is based on 22 seedlings derived from the material collected by Wickham over 100 years ago. An expedition in 1981 to Brazil organized by the International Rubber Research and Development Board has yielded about 14,500 seedlings, which may result in trees with superior characteristics and dramatic yield increases.

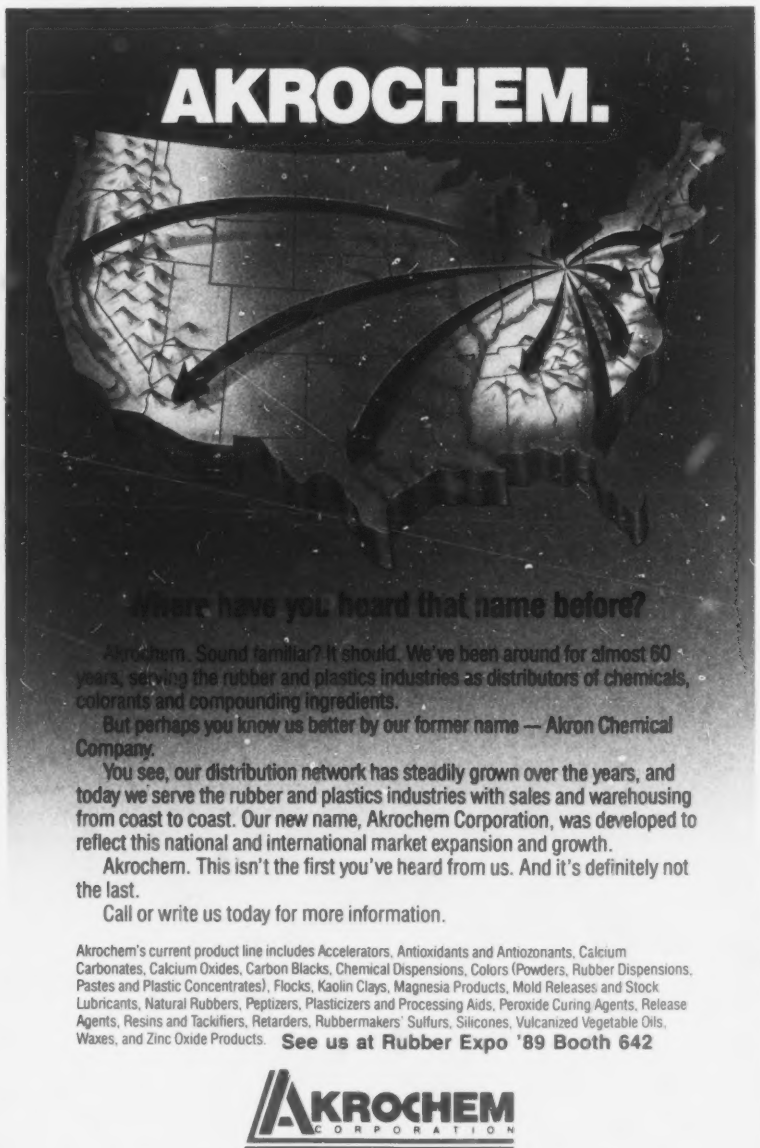
One of the most important advances in propagation techniques has involved the use of grafting to combine the best characteristics of two or more planting materials. This has resulted in the three-part tree: a high yielding trunk is grafted onto a vigorous root stock, and a disease resistant crown onto the trunk. This is now an established commercial practice which allows fast adoption of breeding innovations. A more recent advance is the use of tissue culture techniques: Hevea seedlings have been produced from somatic cells. Ultimately this could eliminate requirements for large nurseries, selection of seedling stocks and budding processes.

Productivity has also been increased by reducing the non-productive immaturity period of trees and by using chemical yield stimulants. Advanced planting materials, produced by budding and the use of core stumps, grow vigorously and uniformly when planted out and can be tapped after four years.

These young trees give high sustained yields with the use of adequate fertilizers and chemical stimulation. Ethylene-based stimulants were discovered in 1970, and their use increases yields throughout the life of the tree, even extending productive life of old trees in combination with controlled upward tapping.

Production can be constrained by labor shortages. Tapping needs skilled labor and less labor-intensive tapping systems have been developed. Half-spiral tapping every four to six days with stimulation gives yields at least as high as the current practice of tap-


World NR production - 1988
total: 5,010,000 m. tons
Rest of the World 11%
Malaysia 33%
B
A
Thailand 19%
Indonesia 24%
A - India 5% B - China 5% C - Sri Lanka 3%. (Percentages rounded to nearest whole number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ping on alternate days, with a labor saving of up to 70%; an added advantage is low bark consumption leading to longer tree life. Mechanization of tapping and collection systems is also being developed, with techniques such as motorized tapping and polybag collection.

Future concerns may include the development of clones suited to different climatic conditions. Work in China has shown that rubber can be grown as far north as 24°, beyond the established growing belt which extends just 15° either side of the equator. China is now the fifth largest producer, with over half a million tons per year despite relatively cool conditions and occasional typhoon winds and droughts. Recently, the RRIM has developed a computer system, Environmax, which recommends the best clones for different soil types and climatic conditions. However, possible changes in the global climate - the 'greenhouse effect' - are a relatively new concern: there are many uncertainties and major climatic changes would lie outside the scope of the current database. What is certain is that natural rubber production is environmentally sound, using renewable, non-polluting natural resources. Any increase in the hectarage of rubber worldwide may help to alleviate problems caused by large-scale destruction of the tropical rain forests.

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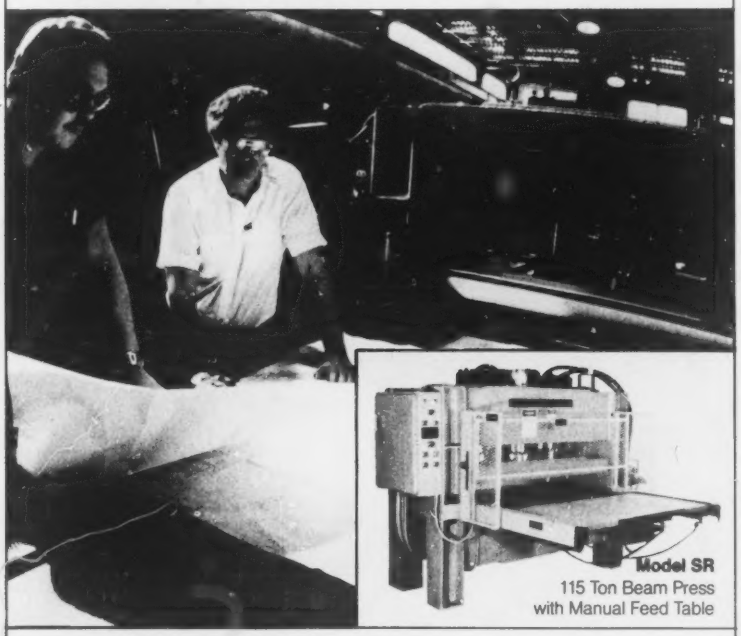

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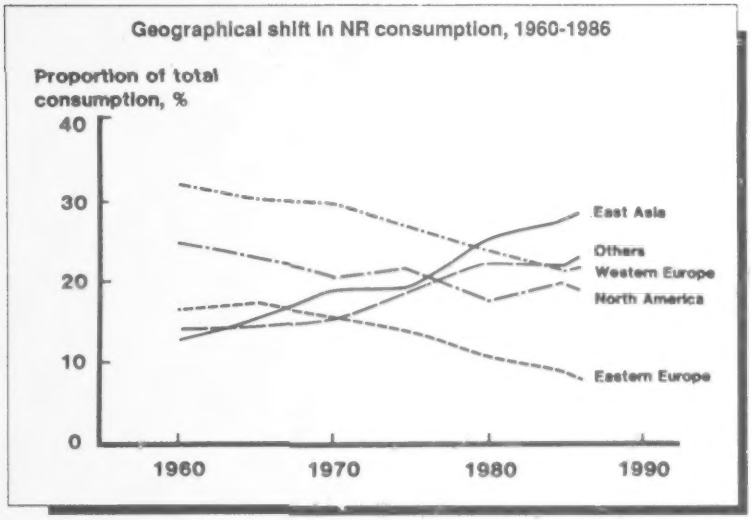
Market patterns

It is generally true that since the early 1950s all natural rubber produced has been sold. It therefore makes good economic sense to increase production in an orderly fashion, both to meet normal growth related to industrial expansion and to increase the market share of natural rubber vis-a-vis the synthetics. Here the activities of the International Natural Rubber Organization have been an important factor: two agreements in the last decade have ensured a degree of price stability and good returns for rubber growers, producing countries are thus confident enough to plan for increased rubber production and consumers are protected from wild price fluctuations.

It has been argued that on its techno-economic merits, natural rubber has the potential to take 42% of the market. Since 1950 natural rubber has been unable to meet increasing world demand for rubber (post-war demand was growing at 6% p.a., while natural rubber production increased at only a little over 2% p.a.) and has lost its predominant market position to the synthetics. Recently, total demand has slowed, with a consequent decline in synthetic growth rates and natural rubber growth remaining steady at 3.7% p.a. Its share of the market over the period 1980 to 1988 has consequently improved from 30% to 34%.

The geographical distribution of natural rubber consumption is changing: in particular, the newly industrialized and developing countries have become more important in the last two decades. Of special interest are the East Asian countries, which have increased their market share by more than 10% since 1970, from about 255,000 tons to over 500,000 tons. The most significant drop in market share has occurred in Western Europe. Consumption has grown only slightly



since 1970 to almost one million tons in 1987, a decline in terms of market share from 30% to about 20%. As well as the obvious growth in Taiwan, South Korea, Hong Kong and Singapore, the natural rubber producing countries are rapidly expanding their domestic rubber consumption. Malaysia, for example, is actively encouraging the growth of resource-based industries, and government policy in this area was laid down in the Industrial Master Plan of 1986. Advantages include purchase of raw materials at source, increased export earnings and added employment.

New materials

It is not enough for the natural rubber producers simply to produce more rubber. Attention must be paid to the needs of the consumers, in terms of quality, processability and presentation of the raw rubber, and the properties required of the final product. In the 1960s, when synthetic rubbers appeared to threaten the viability of natural rubber, the first moves were made in this direction with the development and introduction of the Standard Malaysian Rubber (SMR) scheme in 1965. The other major rubber producing countries have followed suit with their own technically specified rubber schemes, and natural rubber has been transformed from an agricultural commodity to an industrial raw material.

The SMR scheme has not remained static, revisions have been, and will continue to be made in response to consumer requirements and advances in production and processing technologies. Constant viscosity grades were introduced in 1969, and further improvements were made in 1979 when

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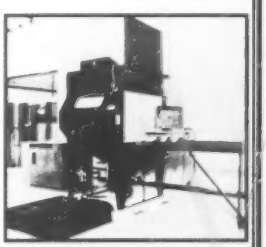

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the scheme was revised. This revision took account of demands for consistent processing within grades, by defining the raw materials going into each grade, introducing a cure indicator for all latex grades and tightening the rules for regrading. A new viscosity stabilized grade, SMR GP, was introduced, to provide a good quality easy-process rubber, potentially available in large volumes.

For the future, the technically specified rubbers will continue to evolve to meet the needs of the consumers. The current demand is for still greater processing consistency to maximize throughput in increasingly automated rubber product factories. At present SMR processing characteristics are indicated only by the PRI test and initial viscosity.

Current research at both RRIM and MRPRA aims to develop tests more directly indicative of processability which can be included as parameters in the scheme. Ultimately Malaysia intends to ensure that all its natural rubber, including latex, conforms to specifications relevant to consumer operations.

Developments such as technically specified rubber have ensured natural rubbers place in the field of general-purpose rubbers. Many attempts have been made over the years to chemically modify the natural rubber molecule and produce a new polymer with special properties. Some attempts have failed because processes have been uneconomical or a new synthetic material has been developed which, for one reason or another, has cornered the market. There have, however, been some success stories - rubber hydrochloride was manufactured commercially for over 30 years as a food packaging material; chlorinated rubber was used in paints; both depolymerized rubber and methacrylate graft copolymers are still in use today.

Until now, natural rubber has been unable to compete with the special-purpose rubbers in terms of properties such as oil resistance and low gas permeability. To meet these challenges, and that of the fastest growing sector, thermoplastic elastomers, new forms of natural rubber have been developed by MRRDB laboratories over the last decade. Both chemically modified epoxidized natural rubber and thermoplastic natural rubber blends are now commercially available.

With epoxidized natural rubber, the property/cost balance is right, and the competing synthetics have been in existence for some time, so the market area is well documented. In epoxidized natural rubber some of the unsaturation of the natural rubber molecule is converted to epoxide groups randomly distributed along the polymer chain. The process is applied in latex using low-cost ingredients, and is now being carried out commercially by Kumpulan Guthrie Sdn Bhd in Malaysia. Two grades, 25% and 50% epoxidized, are currently available under the trade name Epoxyprene.

Epoxidation raises the glass transition temperature of natural rubber and changes the polarity of the polymer. These factors lead to substantial property changes while maintaining the strain crystallizing nature, and therefore high strength of the base polymer.

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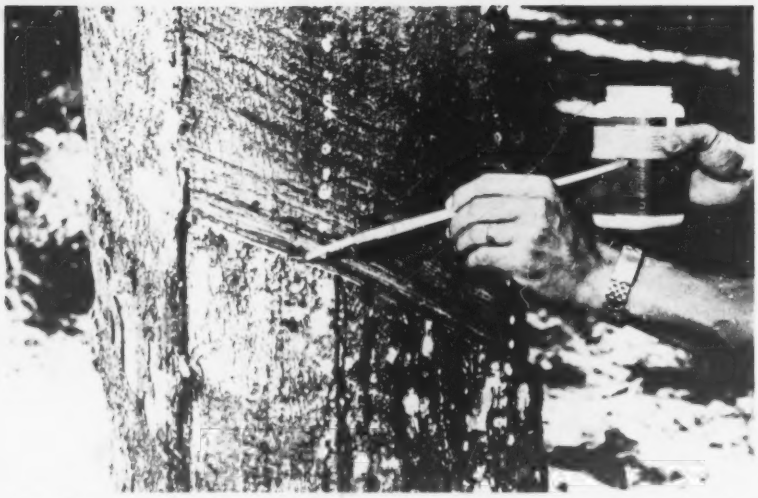

The use of yield stimulants painted on the tapping cut allows trees to be opened early for tapping and fine control of latex production.

The result is increased oil resistance, reduced gas permeability, high damping and compatibility with polar synthetic rubbers such as nitrile, polychloroprene and PVC, leading to good adhesion to these polymers.

Added advantages include good reinforcement by silica without the use of coupling agents, and an interesting combination of good wet grip and low rolling resistance. Its unique combination of properties suggest a wide range of potential applications for Epoxyprene, and some of these have already been extensively evaluated. Applications where light colors and high strength are required are of particular interest. Products investigated include milking inflations, conveyors, seals, tubing, vibration mountings, accoustic dampers, inner tubes, shoe soles and adhesives. The good wet grip and low rolling resistance have led to interest in the use of Epoxyprene for specialist pneumatic or solid tires.

Several attempts have been made to produce a viable thermoplastic natural rubber. Work at MRPRA over the last 20 years has resulted in some interesting materials, but these have either been insufficiently thermoplastic or not economically viable. The latest approach is based on the partial dynamic vulcanization of natural rubber blended with polyolefins, and has produced a material with good technical performance and attractive economics. These thermoplastic natural rubber blends are now being produced commercially, by Teknor Apex in the USA (Telcar DVNR) and Vitacom in the UK (Vitacom DVNR). They have attracted considerable interest in the important TPE market, currently growing at 8-10% per year.

The TPNR blends are characterized by excellent stress strain properties, high strength, good recovery and resistance to heat aging and ozone. Depending on the relative proportions of natural rubber and polypropylene, a range from soft thermoplastic elastomers to semi-rigid rubber-toughened plastics can be produced.

The cost/performance profile of the materials lies between the traditional olefinic materials and the 'engineering alloys'. Potential applications include replacement of rubber vulcanizates and other thermoplastic elastomers in products such as footwear and sports goods, and seals and hoses in the automotive sector. The latter is also the largest potential market for the hard grades, in applications such as bumpers, spoilers and body protection strips.

Other new materials from natural rubber are under investigation at MRPRA and elsewhere, of particular interest are further thermoplastic blends, an oil-resistant thermoplastic elastomer, and low molecular weight liquid rubbers, either as adhesives or as process aids for rubber.

End use research

Improving the consistency in processing of raw natural rubber and developing new materials from natural rubber are two important aspects of MRPRA's role in protecting and extending the market for Malaysian natural rubber. Other areas of work aim to improve formulations and processes, develop new uses, and generally protect the market from erosion by the synthetics. In the past, significant advances have been made in injection molding with natural rubber, the use of rubber in engineering applications, the development of oil-extended natural rubber (OENR) for winter tire treads and improved vulcanizing systems. All this has been backed by fundamental research which has helped the understanding of vulcanization, aging and properties such as elasticity, strength, abrasion and fatigue.

Past work on engineering applications has led to the acceptance of natural rubber as an engineering material, and the market is now one of the largest and fastest growing areas of non-tire natural rubber use. Current research on longevity and dynamic me-

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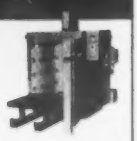

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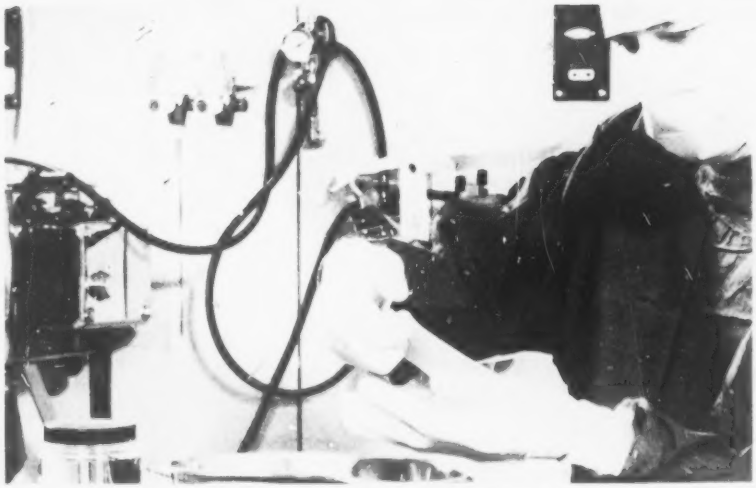
chanical properties has shown that natural rubber is superior to synthetic engineering polymers in many respects, and this basic work adds to the fund of knowledge used to promote natural rubber in engineering. Some interesting success stories include the world land speed record using natural rubber suspension, and the steel-laminated natural rubber bearings for the solid fuel booster rockets used in the space shuttle.

The most interesting development in civil engineering applications, and one with great market potential, is that of earthquake protection. The idea arose about 15 years ago, following widespread adoption of steel-laminated natural rubber bearings for bridges and buildings. Initial computer studies established that the thinking was sound, and MRPRA then instituted extensive development and testing work in collaboration with the Earthquake Engineering Research Center at the University of California, Berkeley. The resulting system was adopted for the Foothill Communities Law and Justice Center in San Bernardino.

This building has been subjected to minor earthquakes and has responded well compared to conventionally protected structures, greatly reducing the forces transmitted to the building. The system differs from other proposed base isolation systems in that the rubber is specially designed to eliminate the need for additional mechanical dampers or wind sway prevention devices.



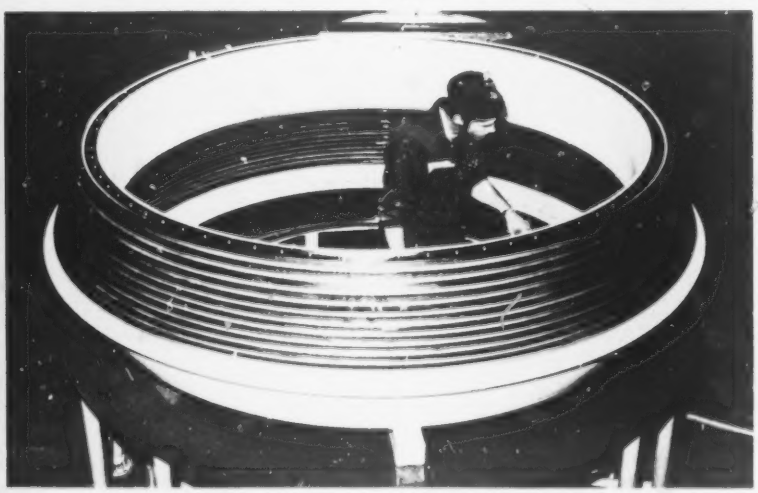
The recent surge in demand for examination and surgeons gloves created high demand for natural rubber latex.

The stability of natural rubber over a wide range of temperatures and frequencies is essential for successful implementation. The system is now being installed in the Los Angeles County Fire Department Control Center and is being considered for several other emergency service buildings in California. Interest is also high in Japan and Europe.

Work has been resumed on OENR in tire treads. Originally developed in the 1970s to provide enhanced grip in ice and snow, OENR is now being assessed in the light of more recent developments: all-season tires and the requirement for low rolling resistance. Compared with standard synthetic compounds, OENR offers improved wear performance at low temperatures, lower rolling resistance and equivalent wet traction, as well as improved snow and ice traction. A slight disadvantage in summer wear rates is more than offset by the low rolling resistance and the low wear in winter.

The wet grip and rolling resistance properties of epoxidized natural rubber have been mentioned already, and MRPRA is assessing its performance in tire treads. Wear performance has been improved by blending with butyl rubber, but at the expense of a slight loss in wet traction. Blends with other polymers and the use of black/silica combinations are now being considered.

A relatively new area of tire research is that of improving natural rubber formulations for truck tire retreads. At one time natural rubber was the preferred material, but its position in this important market has been gradually eroded because of the widespread use of precured retreading where synthetic rubbers are favored. In this process, the good building tack of natural rubber is not a primary consideration, and the profile of the tread reduces the need for natural rubber's low heat-build-up properties. The favored SBR/BR precured retreads give excellent wear performance in long-haul low-severity conditions. New reversion-resistant natural rubber based compounds have been shown, both in



Nozzle bearings for the solid fuel booster rockets of the space shuttle were manufactured from steel laminated NR.

the laboratory and in fleet trials, to outperform the best synthetic treads under a range of service conditions. A major UNIDO-funded project is now underway, involving the building and testing of precured truck tire retreads in the UK and five other countries. Technologists from the rubber producing countries are being trained using the latest retreading equipment, thus contributing to technology transfer.

The most important area of use for natural rubber after tires is in latex applications, and consumption is growing at about 5% per year. Malaysia supplies about 75% of the world's natural latex: about 20% of her natural rubber production is in the form of latex concentrate.

The RRIM and MRPRA are actively involved in improving the properties and quality of the raw material and its products, as well as advising manufacturers on latex use. Areas of research include viscosity and stability, prevulcanization, leaching and lubrication. The current surge of commercial interest in the manufacture of dipped disposable examination gloves has led to work aimed specifically at improvements in the production process for examination gloves. Also of topical interest is the bacteriocidal nature of natural latex foam: here it shows a distinct advantage over polyurethane foam: this could become a 'selling point' to recover some of the market lost to the synthetic material.

Health and safety legislation is now affecting all areas of manufacturing and rubber is no exception. Most of the current interest is in nitrosamines, particularly in baby soothers and teats, in gloves, food contact applications and toys. Raw natural rubber is free of nitrosamines and nitrosatables, and formulations can meet all the current North American and European regulations. Teats and soothers have also been tested for strength properties: natural latex teats have tear, tensile and puncture strengths two to three times greater than silicone teats. The former should therefore meet the requirements of a bite test being developed by the British Standards Institution.

Looking to the future, an area of major importance is likely to be that of polymer blends. Some have said that the development of new rubbers is unnecessary - an almost infinite range of vulcanizate properties may be obtained by blending existing polymers. To be successful, this approach must achieve the correct morphology and optimum crosslink distribution. MRPRA is already working in this area, with a new characterization technique to measure crosslink densities in the separate phases of blends. Once this can be accurately measured, it should be possible to adjust distribution by changing the rubbers and/or curing systems, and ultimately improve blend properties.

Prospects for NR are bright. Research and development has enabled the producing industry to meet demand in terms of both quantity and quality, and enabled consumers to make the best use of top quality materials.

There is no doubt that, with the backing of science and technology, natural rubber will continue to meet the challenges of the competitive world of modern polymers.

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SR - past, present and future

by Maurice Morton, Regents Professor Emeritus of Polymer Chemistry, The University of Akron

Unlike the other synthetic polymers, synthetic rubber was developed to duplicate an already known material, i.e., natural rubber. The latter was actually discovered in America as a result of Columbus' voyages, but did not enter into industrial technology until the early part of the 19th century, i.e., after the development of vulcanization. Since then there were continuous attempts to synthesize this unique elastic material by chemical methods. Incidentally, the name "rubber" is also unique to the English language, most other languages using some form of the original name ("caa-ochoe") used by the American Indians, and is said to have originated in 1770 with Joseph Priestley, who found this material useful in erasing pencil marks.

Early history

Long before the rise of synthetic polymers, which followed Staudinger's discovery of macromolecules in the 1920s, there were many attempts to synthesize rubber. These started shortly after Williams' classical analysis (ref. 1) of natural rubber in 1860, which showed it to consist of isoprene and its homologs. Both Bouchardat (ref. 2) and Tilden (ref. 3) then tried to "convert" isoprene into a rubberlike substance, using heat and strong acids, with little success.

Other investigators then tried using other dienes, e.g. butadiene, 2,3-dimethylbutadiene and piperylene, but were no more successful.

The first synthetic rubber to merit industrial production was the famous (or rather infamous!) "methyl rubber" produced in limited tonnage in Germany during the emergency of World War I. This was a polymer of 2,3-dimethylbutadiene produced by thermal polymerization at 30-70°C in a process lasting from 2-6 months! This rubber was so bad that it was dropped immediately after the war.

First real synthetic rubber

During the 1920s, Staudinger's classic work on polymers and polymerization led to a more intelligent approach to the problem of synthetic rubber.

Thus, both in Germany and the USSR, the polymerization of butadiene by sodium metal produced the first commercial synthetic rubber, called "Buna" rubber, for obvious reasons. The Russians stayed with sodium polybutadiene for the next two decades, until the end of World War II, while the Germans changed over to the emulsion copolymerization of butadiene and styrene during the 1930s. This was still called "Buna" rubber, although they indicated the comonomer styrene by the name "Buna S". (They also developed nitrile rubber at that time, by the copolymerization of butadiene and acrylonitrile, naming it "Buna N".)

It was Buna S that was the basis for the rise of the giant synthetic rubber industry in the United States during the rubber emergency of World War II, starting with the shutdown of the supply of natural rubber from the Far East after Pearl Harbor.

Prior to that, there was no real interest in general-purpose synthetic rubber in the U. S., the only developments being in special oil-resistant rubbers, such as Thiokol in 1930 and Neoprene in 1932.

The phenomenal rise in production of butadiene-styrene copolymer in the USA between 1942 and 1945 represented a remarkable feat of technology, second only to the development of the atomic bomb, and led to a complete change in the world picture.

At that time, the U. S. was consuming about 1 million tons of natural rubber per annum, or roughly one-half of the world supply. We had a stockpile of about a one year's supply. The Government Synthetic Rubber Program then spent $700 million to build 51 plants to produce the necessary synthetic rubber to meet that demand, starting virtually from scratch. How successful that effort was is shown in table 1 (refs. 4 and 5). Today, this useful tire rubber is the dominant synthetic rubber and is the main component of automobile tires.

At the same time as the above developments in the rise of butadiene-styrene rubber, the Standard Oil Company (ref. 6) also used its contacts with the German company, IG Farbenindustrie, to obtain information leading to the development of butyl rubber. This was the first of the low-unsaturation synthetics so necessary for rubber of superior weathering properties.

Table 1 - world SR production 1933-45 (thousands of long tons)

Year	USSR (SK rubber)[a]	Germany (Buna S)	USA (GR-S)[b]	Canada (GR-S)
1933	2.2	----	----	----
1934	11.1	----	----	----
1935	25.6	----	----	----
1936	44.2	----	----	----
1937	25.0	2.1	----	----
1938	53.0	4.0	----	----
1939	78.5	20.6	----	----
1940	----	37.1	----	----
1941	----	65.9	0.23	----
1942	----	94.2	3.7	----
1943	----	110.6	182.3	2.5
1944	----	97.5	670.3	32.1
1945	c	----	719.4	36.6

[a] Sodium polybutadiene

[b] Wartime name for butadiene-styrene copolymer (now SBR)

[c] At the conclusion of the war, the USSR was producing about 100,000 tons of SK rubber.

Recent developments

The last 25 years witnessed two giant advances in synthetic rubber and rubber technology:

- stereospecific polymerization, and
- block copolymers (thermoplastic elastomers).

Stereospecific polymerization, i.e. the synthesis of such "stereo" rubbers as cis-1,4-polyisoprene (natural rubber) and cis-1,4-polybutadiene, as well as of the ethylene-propylene copolymers (EPDM), was the result of a revolutionary discovery of stereospecific polymerization catalysts by Ziegler in Germany and Natta in Italy. Block copolymers, especially the styrene-butadiene-styrene triblock copolymers which lead to thermoplastic elastomers, arose from the application of "living" anionic polymerization systems. This development opened a whole new area of rubber products, where the rubber is permanently thermoplastic, because it consists of a two-phase material in which a plastic component (e.g., polystyrene) is finely dispersed within the rubber matrix, to which it is chemically bonded, and thus acts as a thermoplastic crosslinking agent. This, then, made injection molding a viable technology in the rubber industry.

Synthetic rubber today

The role of synthetic rubber today is well illustrated by looking at rubber consumption in the USA. We produce a total of about 2 million metric tons of synthetic rubber per annum (of which about 2/3 consists of the two principal tire rubbers, SBR and polybutadiene). In contrast, the U.S. consumption of natural rubber represents only about 1/4 of total rubber use. On a world scale, the ratio of natural to synthetic is somewhat more favorable (about 1/3).

Synthetic rubbers today fall into two broad categories, which govern their technology. These are:

- Rubber vulcanizates, where the original long-chain macromolecules are crosslinked into a permanent net-

Table 2 - synthetic rubber vulcanizates

Name	Chemical name	Chain unit structure	Vulcanizing agent	Properties and uses
SBR	Butadiene-styrene copolymer	$[(CH_2\text{-}CH{=}CH\text{-}CH_2)_3CH_2\text{-}CH(C_6H_5)]$	Sulfur (peroxides)	General purpose, mainly for tires.
Polybutadiene	Polybutadiene	$[CH_2\text{-}CH{=}CH\text{-}CH_2]$	"	Excellent tire tread wear, low temp. prop.
Polyisoprene	Polyisoprene	$[CH_2\text{-}C(CH_3){=}CH\text{-}CH_2]$	"	General purpose, same as natural rubber.
EPDM	Ethylene-propylene-diene copolymer	$[(CH_2\text{-}CH_2)(CH_2\text{-}CH(CH_3))_1\text{-diene-}]$	"	Excellent weathering. Wire and cable, one-ply roofing.
Nitrile	Butadiene-acrylonitrile copolymer	$[(CH_2\text{-}CH{=}CH\text{-}CH_2)_{2\text{-}8}(CH_2\text{-}CH(CH{\equiv}N))]$	Sulfur	Oil resistance. Gasoline hose, automotive engine parts.
Butyl[a]	Isobutene-isoprene copolymer	$[(CH_2\text{-}C(CH_3)_2)_{50}CH_2\text{-}C(CH_3){=}CH\text{-}CH_2]$	Sulfur	Low air permeability good aging. Tires, insulation.
Neoprene[b]	Polychloroprene	$[CH_2\text{-}C(Cl){=}CH\text{-}CH_2]$	Metal oxides or diamines	Oil resistance, high gum strength. Molded parts, rubber hose and gloves.
Polyurethanes	Polyurethanes	$[OROC\text{-}NH\text{-}R'\text{-}NH\text{-}C(=O)]$	Urethane functional groups	Excellent abrasion resistance, range of hardness. Footwear, toys, foam.
Fluorocarbon	Fluorocarbon copolymer	$[(CH_2\text{-}CF_2)(CF_2\text{-}CF(CF_3))]$	Diamines	Excellent heat and solvent resistance. Used for extreme conditions.
Silicone	Polysiloxanes	$[Si(CH_3)_2\text{-}O]$	Peroxides	Retention of prop. over broad temp. range. Gaskets, tubing.

[a] Includes chlorobutyl and bromobutyl
[b] Includes Hypalon (a chlorosulfonated polyethylene)

work by reaction with a chemical crosslinking agent (vulcanization). These are the descendants of Charles Goodyear's original process of sulfur vulcanization of natural rubber.

• Thermoplastic elastomers, where the rubber chains are bound into a network held together by thermoplastic domains, and which can therefore be molded and remolded by heat.

The rubber vulcanizates

The most recent edition of Rubber Technology (ref. 7) provides a good idea of the large variety of synthetic rubbers available today. These are listed, by type, together with their chemical structure and properties in table 2. No attempt was made to show the various grades available for each elastomer, since these generally comprise large numbers, and are available in the industrial literature.

An examination of table 2 reveals two remarkable features: a) the wide range in properties (and uses) of the various synthetic rubbers, and b) the variety of crosslinking agents required to vulcanize the elastomers.

It is obvious that synthetic rubbers today offer a wide variety of physical and chemical properties not obtainable from natural rubber. Thus the legendary impermeability of butyl rubber to air has revolutionized tire construction. The impressive oil and solvent resistance of nitrile has enabled the use of rubber in many necessary applications, including the ubiquitous gasoline hose at service stations. The silicones, with their unique molecular structure of alternating silicon and oxygen atoms, have enabled the use of rubber over a broad range of temperatures, from sub-zero (refrigerator door gaskets) to oven heat (200°C). Then we have the unbelievable fluorocarbon rubbers, with their ability to resist a variety of solvents as well as temperatures as high as 300°C (48 hrs.) and 200°C for continuous use.

The unique "castable" polyurethanes exhibit amazingly high resistance to abrasion, a highly desirable property for footwear and toys, subjected as these products are to the known destructive propensities of feet and kids, respectively. The highly saturated hydrocarbon rubbers, butyl and EPDM, have brought a new dimension into the long-term aging and weathering of rubber insulation. In fact, EPDM rubber is enjoying a rapid growth as single-ply roll-roofing material, replacing the venerable asphalt-impregnated roofing.

Some of the more recent developments in synthetic rubber have been equally exciting. Thus the hydrogenated nitriles have added the extra aging property of saturated hydrocarbons to the well-known solvent resistance of the nitriles. The propylene oxide rubbers have unusually high resistance over a range of temperatures, even better than natural rubber, as well as good ozone resistance. The polyalkylene sulfides, one of the first synthetic rubbers produced in this country, have outstanding solvent, aging and ozone resistance.

As for the vulcanization process, it is obvious from the list in table 2 that the crosslinking of synthetic rubber chains into networks has gone far beyond the original sulfur-based process

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pioneered by Charles Goodyear in 1839. This is natural rubber, and can be crosslinked by other agents. Thus the chlorine-containing Neoprene is best crosslinked by the reaction of the allylic chlorine atoms (from 1, 2-enchainment) with metal oxides, such as magnesium or zinc oxide. Diamines can also react with this polymer, as a crosslinker, and the same reaction can be carried out with the chlorine or bromine atoms of the halobutyls. As a matter of fact, one of the methods for making otherwise incompatible blends of butyl with natural rubber or SBR is to use chlorobutyl or bromobutyl in a zinc oxide/sulfur vulcanization system. Diamines are also the crosslinkers for the fluorocarbon rubbers, by reaction with the active fluorine atoms on the polymer chains.

When the polymer chain has no satisfactory reactive points, such as active side-groups or double bonds, the organic peroxides can be relied on to crosslink the chains. Hence peroxide vulcanization is used for silicone rubber and for some of the low-unsaturation hydrocarbon rubbers. This type of crosslinking depends on the ability of the peroxide to abstract hydrogen atoms from hydrocarbons, creating radicals along the polymer chain, and these subsequently couple to form crosslinks. Hence this method is useful when no other reactive groups are available as substituents on the rubber molecule.

The thermoplastic elastomers

This class of synthetic rubbers had its start approximately 25 years ago as a development of anionic "living" polymerization (refs. 8 and 9). The latter refers to the polymerization of monomers, such as butadiene, isoprene, styrene, etc., by organometallic initiators, preferably of the lithium type. These systems are referred to as "living" since each initiator molecule is capable of starting a polymer chain, which then continues to grow as long as any monomer is available. In other words, with suitable precautions, the growing chains never terminate (or "die"). Hence, these are ideal systems for the synthesis of block copolymers, by sequential addition of different monomers.

The type of block copolymers which originally gave rise to the thermoplastic elastomers were the triblock copolymers, polystyrene-polybutadiene-polystyrene (ref. 10), developed by the Shell Chemical Co. under the tradename of "Kraton." A schematic of the molecular structure and morphology of these materials is shown in figure 1. As can be seen, the polystyrene blocks, being incompatible with

Figure 1

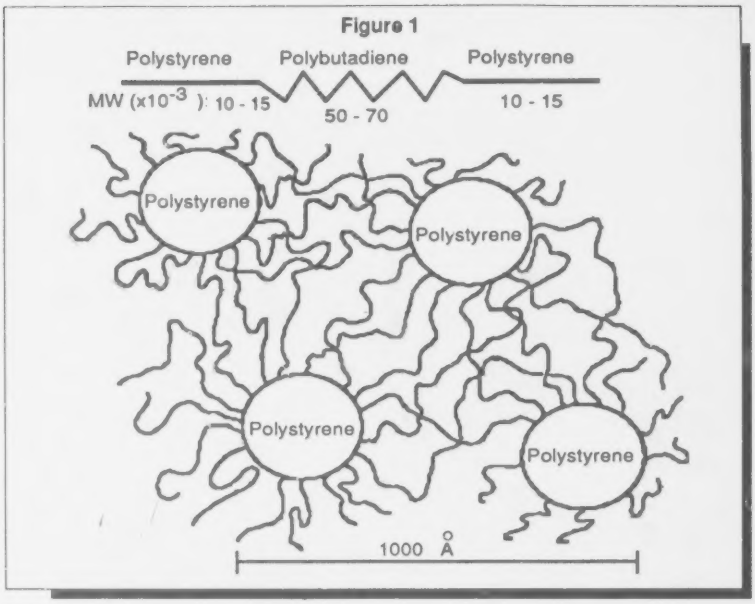

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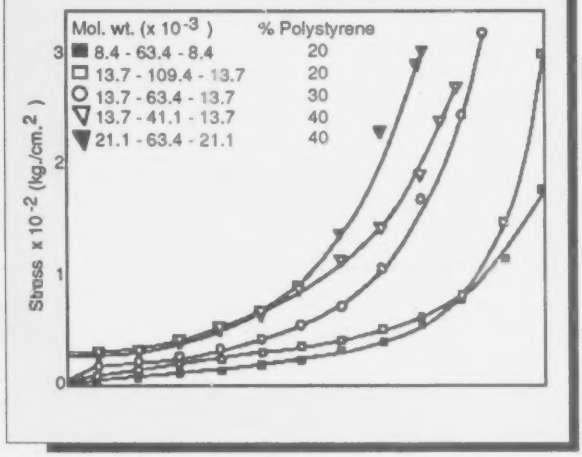
Figure 2



the polybutadiene, separate out as domains dispersed in and chemically bound to the polybutadiene matrix, thus forming a rubber network held together by thermoplastic polystyrene "crosslinks." It is not surprising, therefore, that such a material exhibits the properties of a vulcanized rubber at moderate temperatures (resistance to flow, good retraction, etc.) but flows freely at elevated temperatures.

The tensile properties of such thermoplastic rubbers are well illustrated in figure 2 and table 3 for a series of styrene-isoprene-styrene triblock copolymers of varying composition and molecular weight (refs. 8 and 9). It can be seen that the modulus of these rubbers is governed mainly by the polystyrene ("filler") content, more or less independently of molecular weight, while the tensile strength is largely independent of both factors, except at very low molecular weight of the polystyrene. What is also notable is the very high strengths obtainable in these materials. This is undoubtedly due to the high regularity of block size obtained in anionic polymerization, leading to a very uniform morphology, which, in turn, results in a uniform network structure. The sharp drop in tensile strength at low polystyrene levels is obviously due to the much greater compatibility of the short polystyrene chains with the polyisoprene, resulting in a homogeneous rather than a two-phase morphology, to the point where a network no longer exists.

The development of these triblock copolymers thus gave rise to a whole new concept of "thermoplastic rubber," where a network of "soft," rubbery chains is held together by a dispersion of a "hard" thermoplastic phase. Since then, this concept has been applied to a variety of block and graft copolymers having different properties tailored to specific uses. For example, although the styrene-diene triblock copolymers can be ideally

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synthesized by anionic polymerization, they suffer from the poor temperature and solvent resistance of the polystyrene and the poor aging of the polydiene. (This has been somewhat improved by hydrogenation of the polydiene blocks.) Unfortunately, the anionic mechanism of polymerization is limited to very few practical monomers. Hence other approaches have been used.

One highly desirable thermoplastic elastomer (TPE) is, of course, a block (or graft) copolymer of EPDM and polypropylene, which would have the good aging of the EPDM and the good temperature and solvent resistance of the polypropylene "crosslinks." However, it has not been found possible to create such a block copolymer by a "living" polymerization method. Instead, a mixed block and graft system can be made by subjecting a mixture of the two polymers to high shear at elevated temperature, at which point the linear polymer chains are continuously ruptured and recombine into various block and graft copolymers. The morphology of such materials is much more irregular than that of the anionic triblocks so that tensile strength drops, as expected, but the desirable improvement in resistance to temperature and solvents of the "olefinic TPE's" is notable.

Table 3 - tensile strength of SIS block copolymers

Wt. % styrene	Molecular wt. ($\times 10^{-3}$) S	I	S	Tensile strength MPa
40	21.1	63.4	21.1	31.0
40	13.7	41.1	13.7	30.6
30	13.7	63.4	13.7	32.1
20	13.7	109.4	13.7	27.0
20	8.4	63.4	8.4	16.0
19	7.0	60.0	7.0	2.2
11	5.0	80.0	5.0	0

Using various polymerization and interpolymer reactions, a constantly increasing array of thermoplastic elastomers has become available during the past decade or so. A list of commercially available types is shown in table 4, but this may already be outdated by the time of publication of this article, since this is a rapidly expanding field! As can be seen, these TPEs have been classified according to the nature of the "soft" and "hard" segments making up their structure, since their thermal and solvent resistance are mostly dependent on the nature of the "hard" blocks, which form the network junctions, and these can be either crystalline or amorphous. No attempt has been made to list all of the products by trade names, but the latter may be found in the appropriate technical publication (refs. 11 and 12).

The future

The art of forecasting may appear to be quite difficult but is actually relatively simple. Since "the future" usually encompasses a period of anywhere from 20 years to centuries, the time of reckoning is quite far away (and often past the lifetime of the prophet)! Hence, if the prophecy is proven completely wrong, no one would remember it anyway. But should it actually be vindicated, there could always be

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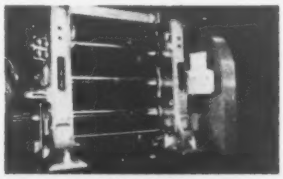
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Table 4 - classification of commercial thermoplastic elastomers

Nature of hard phase	*Type of polymer*	*Chemical composition*	
		Hard phase	*Soft phase*
Amorphous	Triblock (SBS)	Polystyrene (s)	Polybutadiene (B)
Amorphous	Triblock (SIS)	Polystyrene	Polyisoprene (I)
Amorphous	Triblock S-EB-S)*	Polystyrene	EB copolymer*
Crystalline	Multiblock	Polyester	Polyester**
Crystalline	Multiblock	Polyurethane	Polyether (or polyester)
	Multiblock		
Crystalline	Multiblock	Polyamide	Polyether
Crystalline	Graft/blend	Polypropylene (or polyethylene)	EPDM

*EB refers to poly(ethylene-co-butene-1)
**Amorphous polyester

some scholar who may discover it in the literature and loudly marvel at the remarkable powers of the long-gone soothsayer.

In the case of synthetic rubber, it might be best to consider possible future developments separately for the vulcanizates and for the thermoplastic elastomers.

The rubber vulcanizates

On reviewing the array of vulcanizates listed in table 2, one has the feeling that there is now available a variety of polymer chain structures offering a wide range of chemical and physical properties.

It is difficult to see what new types of chain structures could be developed that would offer substantial improvements in properties and still be economically feasible. Short-range improvements in base polymer, compounding and vulcanization can be expected in the immediate future, but revolutionary changes in the distant years are difficult to anticipate.

The most challenging problem in rubber technology is the creation of a rubber which could withstand ultra-high temperatures, i.e., ca. 1000°C. This has been a goal of aerospace scientists and engineers for many years, since such a material would be of special importance for use in rocket engines, etc.

It is obvious that organic polymers could not fill this need; the question is whether an "inorganic" polymer could be developed having the necessary rubbery properties. To date a number of inorganic materials have been used for such applications, but these have been rigid ceramics, not rubbers. Hence the solution of this problem lies in the future.

The thermoplastic elastomers

Since this development is so recent, it is not difficult to predict that it has a very promising future. This is especially true because of the unique potential of these materials.

In the first place, they have enabled the use of rapid molding methods, e.g., injection molding, for the manufacture of rubbery products. Secondly, they can be used to prepare a range of materials, from soft to hard rubbers all the way to high-impact plastics.

The combinations of the various polymers shown in table 4 represent only the beginning of a new technology. As a matter of fact, these materials are sometimes referred to as "elastoplastics" instead of thermoplastic rubbers.

The significance of this is that it is leading to the disappearance of the boundary between rubber and plastics, and this is of special relevance to the automotive industry, which is one of the major consumers of these materials.

Both in the short term and from a long-range view, therefore, these materials appear to represent the "wave of the future."

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Developments in compounding

by Howard L. Stephens, Emeritus Professor of Polymer Science, The University of Akron

The problem of estimating the future needs when related to compounding depends on the compounder's relationship to his working environment.

Perhaps this is best illustrated by the diagram described by B.S. Garvey, Jr. in the first edition (1959) of "Rubber Technology" (figure 1).

However, it is obvious from the flow diagram that only a large organization would have all of the departments as shown above. Smaller companies in many instances do not have research groups to back up product development and production.

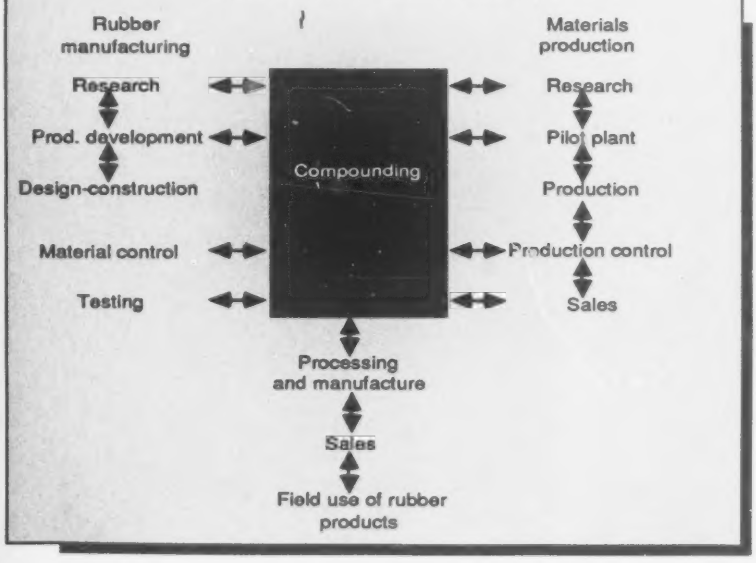
In these instances, the chief compounder (or only compounder) has to depend on the information received from material manufacturers and suppliers. But the diagram does reflect the ideal situation regarding compounding in the 1980s and in future years even though the idea was written over 30 years ago. The compounder's function is best described in the 1978 Vanderbilt Rubber Handbook as follows:

"He must be able to select the proper elastomers and additives available to meet the conditions of the finished product. This requires a thorough understanding of the following:

- Properties of the elastomers available.
- Vulcanization or curing systems to give the potential properties needed.
- Modifying materials which give the required physical properties and aging resistance.
- Compounds must be able to process properly depending on processing equipment.
- Commercial compound design, and
- How to test and evaluate raw materials and finished products."

From this standpoint, the compounder must be well aware of the changes being made in the production and availability of elastomers and the ingredients used in rubber manufacture. This will be the basis for the following discussion in this article.

Figure 1 - flow diagram circa 1959



Availability of ingredients

A survey was made using the "Blue Book: Materials, compounding ingredients, machinery and services for rubber" for three periods, 1968, 1980 and 1989 to illustrate the changes occurring in the industry over this period of time in order to show trends that occur due to OSHA requirements, buy-outs and mergers.

Naturally, this source has changed its contents over this time period, however, the trends are still a good indication of how the industry has changed or may change during the next decade or two. The number of suppliers has increased over the past 10 years, as indicated in table 1.

From this information, it is obvious that there is still a large increase in the number of suppliers over this period, and furthermore, the growth in the use of custom mixers has increased 230%, indicating that this is a cheaper way of processing or that the custom mixer is supplying a quality product to the smaller producer of molded rubber products, thus eliminating his need for expensive mixing and testing equipment.

Elastomers

The International Institute of Synthetic Rubber Producers (IISRP) indicates that total rubber consumption will increase 11% from 1988 to 1993 (10.9 to 12.1 million tons). How this increase will affect production and sales of each individual elastomer remains to be seen.

Table 2 shows the number of listings for each elastomer for these periods (Blue Book data).

There has been no change in the number of natural rubber grades over the last 10 years, however, production is estimated to increase 9.8% from 1988 to 1993. Over the last 20 year period (1968-1989), only small changes in listings occurred for the acrylics (13 to 16), chlorosulfonated polyethylene (4 to 6), polysulfides (10 to 15) and little or no change for S-B resins.

Large increases occurred for the

Table 1 - Blue Book suppliers

	1968	1980	1989
Material and ingredient suppliers	Not listed	288	344
Custom mixing	Not listed	23	57
Machinery and equipment suppliers (with products)	Not listed	275	332

ethylene-acrylics (1 to 7), EPDMs (11 to 101), fluorocarbons (10 to 75), nitriles 106 to 229), butadienes (25 to 47), chloroprenes (25 to 67), silicones (71 to 104), and especially the thermoplastic elastomers (8 to 66) and the urethanes (42 to 90).

The large growth in EPDMs is mainly due to its use in single ply roofing material. EPDM is now second in usage after the conventional roofing materials, replacing Hypalon as the most popular elastomer for this usage.

Listing decreases occurred for butyl (28 to 22), polyisoprene (13 to 8), and especially for the various types of SBR (436 to 164). This decrease for SBR shows that the number of producers is decreasing, but predicted SBR usage will increase 8.8% from 1988 to 1993, as predicted by the IISRP. It must be noted that the number of listings in many cases either indicates a reduction in the number of producers or a decrease in the grades that are available. For example, the number of black-oil masterbatches and oil masterbatches has decreased probably due to a decrease in the types of oil and blacks available.

Table 3 illustrates the rapid growth in the number of producers of thermoplastic elastomers since the production of the Solprenes in 1963 and the Kratons in 1964.

Table 2 - number of listings

Elastomer	1968	1980	1989
Natural rubber			
Standard international grades	31	35	35
TSR (SMR types)	3	9	9
Specially prepared grades	4	6	6
Modified	2	4	4
Total	40	54	54
Synthetic rubbers			
Acrylics	13	16	16
Chloronated polyethylene	0	4	14
Chorosulfonated polyethylene	4	7	6
Epichlorohydrin	2	5	8
Ethylene-acrylic	1	1	7
EPM	1	7	10
EPDM	11	50	101
Fluorocarbons	10	28	75
Butyl	28	16	22
Nitrile	106	166	229
Butadiene	25	23	47
Chloroprene	25	43	67
Polyisoprene	13	5	8
Polynorbornene	0	0	5
Polysulfides	10	8	15
Silicones	71	55	104
Synthetic rubbers			
SBRs			
Solution and block	NL	31	35
1000 (Hot)	39	25	18
1500 (Cold)	52	28	18
1600	32	17	9
1700	67	22	14
1800	74	26	29
1900	35	11	9
Cold latex	49	16	7
Hot latex	88	34	25
Styrene-isoprene	0	1	6
Thermoplastic elastomers	8	10	66
Transoctenamer	0	0	1
Urethanes	42	84	90
Vinyl acetate/ethylene	0	2	10
S-B resins	11	4	11
Reclaims and regrinds	33	33	33
Reprocessed synthetic rubber	0	7	35

Elastomer latices

Table 4 shows the listing for the various elastomeric latices over the same time period (1968-1989). For each elastomeric latex type there was a decline in the total number of listings with the disappearance of fluoro, isoprene-acrylonitrile, butadiene, butyl and isoprene latices. However, these are probably available on a special order basis. Both nitrile and SBR latices declined in their listings (45 to 16) and (25 to 13), respectively.

Elastomeric latices

In all cases there was a decline in the total listings for each latex, with the complete disappearance of fluoro, isoprene-acrylonitrile, butadiene, butyl and isoprene latices. Apparently there was insufficient demand for these products.

One of the greatest failures has been the inability of anyone to produce a synthetic polyisoprene latex with all the characteristics of natural rubber latex. The only latex listed in 1969, produced by Shell, never had all the properties desired in a latex of this type.

Although SBR listings have decreased from 25 to 13, the predicted usage of these latices will increase 8.8% from 1988 to 1993 (IISPR data).

Compounding ingredients

Table 5 shows the listings for some of the major ingredients used in elastomeric compounds for both dry rubber and latex materials. It should be noted that many of the listings for individual materials are high as there are so many forms available for the same ingredient, ie., powdered, rod-form, pastes, dispersions, elastomeric blends and micro-encapsolates, etc.

However, predicted production will increase from 382 to 400 million pounds from 1988 to 1989, according

Table 3 - thermoplastic elastomers

	Number of manufacturers		
Product type	1975	1985	1987
Polyurethane TPE	3	8	10
Styrene-diene blocks	2	3	6
Polyolefin blends	1	7	18
Styrene-EB blocks	1	1	1
Copolyester-ester	2	4	5
PVC-TPE	0	2	3
Polyamides	0	2	3
Others	1	1	4
Total	10	28	50

Table 4 - latex listings

Elastomeric latices	*1968*	*1980*	*1989*
Acrylics	19	14	22
Fluoro	0	2	0
Isoprene-acrylonitrile	0	1	0
Natural rubber	12	12	14
Nitrile	45	15	16
Chloroprene	13	14	13
Styrene-butadiene	25	50	13
Vinyl pyridine	3	7	5
Butadiene	1	0	0
Butyl	1	0	0
Isoprene	2	0	0

to a Chemical and Engineering News April 17, 1989 story. All U.S. producers (>20) are running at full or near capacity for the manufacture of these items. The C&E News article indicates that there are over 50 suppliers in the U.S. alone with some of the manufacturing in other countries. This figure does not include fillers, colorants, plasticizers and softeners. It is interesting to note that there is a trend toward supplying many of the compounding ingredients as dispersions or elastomeric blends. Some examples are shown in table 6.

Many of the dispersions are for latex use and this is especially noticeable with antidegredants and inhibitors since a large decrease has occurred since 1968. The increase in elastomeric ingredient blends reflects both the storage stability and the ease of measuring and using these materials.

The decrease in carbon black listing from 1980 to 1989 shows the effect of eliminating the manufacture of channel blacks and several grades of both thermal and furnace blacks.

In the third edition of "Rubber Technology," J.T. Byers predicts that perhaps 11 grades of carbon black have a "questionable future" and may be dropped due to decreasing use and some of the structure levels may be discontinued from manufacture.

The Blue Book in 1980 listed 40 grades as compared to 32 in the 1989 edition. Apparently the trend is continuing. The compounder must be aware of these changes and be willing to make substitutions when necessary before supplies are not available. He needs the aid of both the producer and supplier to prevent serious problems in his production of vulcanized goods. This is also important when considering all of the compounding ingredients that he uses.

Table 5 - compounding ingredients

Rubber compounding ingredients	*1968*	*1980*	*1989*
Accelerators	277	437	718
Activators	200	226	384
Retarders	25	45	47
Vulcanization agents	140	254	433
Antidegradants and inhibitors	356	341	476
Chemical and heat stabilizers	135	72	62
Homogenizers	0	4	13
Peptizers	31	14	25
Processing aids and dispersing agents	87	126	205
Tackifiers	122	166	167
Platicizers and softeners	741	570	601
Short fiber reinforcing materials	0	0	5
Carbon blacks	117	158	131
Other black materials	4	11	22
Non-blacks	362	320	423
Adhesive, bonding and sealing agents	72	147	186
Blowing agents and blow promoters	58	63	76
Dusting, dipping and washing materials	64	103	129
Finishes	0	51	62
Lubricants (molds and internal)	184	209	237
Odorants and non-staining agents	54	16	13
Latex compounding materials			
Anti-blocking agents	6	7	10
Anti-foaming agents	36	54	51
Anti-webbing agents	3	2	5
Coagulants	11	15	12
Creaming agents	1	3	1
Dispersing agents	42	39	40
Gelling agents	11	10	14
Preservatives	4	9	5
Stabilizers and emulsifiers	93	55	8
Thickening, viscosity stabilizers and reducers	19	20	26
Wetting agents	7	21	10

Summary

The usage and supply of the basic materials utilized by the compounder seem to be on an even keel since many of the items still available may function to produce a satisfactory vulcanizate, however, he has to be prepared to replace items as they are discontinued or eliminated by OSHA's requirements.

Fortunately, there are newer modifications of elastomers being developed (hydrogenated nitrile and epoxidized natural rubber are two examples) which aid the compounder in the selection of basic elastomers. In the past few decades, instrumentation has been computerized to the point where mixing, processing, vulcanization and testing data is stored and can be recalled when needed.

This type of instrumentation, curemeters for example, has greatly aided the compounder in developing compounds and aids in maintaining quality control of production items, as the search for uniformity will continue.

Table 6 - blends and dispersions

		1968	*1980*	*1989*
		Listings available		
Accelerators	Dispersions	35	56	67
	Elastomer blends	39	134	183
Activators	Dispersions	8	42	38
	Elastomer blends	11	57	69
Vulcanization agents	Dispersions	16	40	39
	Elastomer blends	13	79	89
Antidegradants and inhibitors	Dispersions	50	15	13
	Elastomer blends	0	4	12